Towards Self-Sustaining Farms:

Renewable Energy and Energy Efficiency on Small Farms in Vermont

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I. **Healthy Local Communities**

a. Introduction

This semester in the Environmental Studies Senior Seminar, we studied Healthy Local Communities. Plowing through a range of authors, we came to a better understanding of what each of the terms Healthy, Local, and Community mean, and how they interact with each other. We looked to economists, philosophers, sociologists and religious leaders in hopes of finding some common ground among them, and found that a few major themes are present in nearly every work.

We discovered, firstly, for communities to exist at all there need to be networks of people in respectful, reciprocal relationships. Some authors, like Wendell Berry and David Korten, point out that interdependence among and within communities, natural and human, must also be spiritual. For economists, networks of people and reciprocation form the base for dynamic, innovative markets. Almost all of the authors we read agree that a healthy community is one that sustains itself and the natural environment for generation after generation.

For a community to be healthy and self-sustaining at any scale, it must also be somewhat self-reliant. For example, a city fed by conventionally grown and imported food, no matter how tightly-knit the social fabric is, would not survive an energy crisis. Local production of basic needs such as food, energy and shelter renders a community system diversified and resilient.

Since the industrial revolution, American society has progressed away from hometown, family-oriented lifestyles and towards a more individualized yet larger-scale, globalized world. The average bite of food travels 1,500 miles before reaching our plates, we outsource jobs to countries thousands of miles away, fewer people know their neighbors, and the divorce rate remains high. According to the 2005 US Census, the average American travels more than 25 minutes a day to get to work and less than 6% of these people use public transportation. Even in Vermont, a more rural and slower-paced state than most, only half of the residents were born in the state, and almost 15% lived in a different house just a year before the census was taken (US Census Bureau, 2005).

Despite our increasing population, affluence and mobility, social and environmental factors are pushing the United States toward more home-based lifestyles.

National security, not to mention the very air we breathe, is compromised by a dependence on foreign oil. Many experts have theorized that oil supplies will disappear or be interrupted even if our habits are changed. Americans will inevitably face a significant change of lifestyle in our future. Numerous authors, such as Wendell Berry, John McKnight and James Kunstler, advocate "traditional" communities as sustainable living models. "Traditional" communities connote a certain kind of community that may be simpler and less technology-dependent. Keeping these ideals of traditionalism in mind, we sought to combine the most useful and relevant principles from past and present models of community.

Our project focuses on ways Vermont farmers can begin to be more energy efficient and independent, as well as an integral part of a local, self-reliant community. These measures contribute to healthy local communities. We recognize that conceptualizing 'healthy local communities' is complicated by myriad variables that shape the social, individual and environmental needs of a given community. Further, rural Vermont is not isolated from global economic forces. Thinking globally calls for acting globally, too. By focusing on human agency, cultural values, and innovation, our vision of healthy local communities is proactive rather than reactive to global problems of oil dependence and climate change.

In this study, we focus on Vermont's small farms, which can potentially represent an alternative to the current global model of agriculture. This new model is based on reclaiming the local economy, fostering culture, and reconnecting communities.

b. Project Background—Energy Use on Farms

The rising cost of on-farm electricity usage is a constant challenge for farmers. Various groups such as the Northeast Organic Farming Association of Vermont (NOFA-VT), the Vermont Biofuels Association, Central Vermont Public Service, and Efficiency Vermont, are engaging on the issue of on-farm energy efficiency and energy capture. Every farm has the potential to be self-sustaining in its energy production. The 2006 report, "Recommendations to the Sustainable Agriculture Council," states, "Questions abound regarding baseline information on the state's energy footprint and potential for local energy generation from farms. Several avenues of research would help farmers,

farm energy companies, and policy makers better understand the array of options" (Vermont Sustainable Agriculture Council, 2006).

This project aims to explore the possibilities for increasing energy efficiency and the feasibility of making small farms in Vermont self-sustaining energy producers through local, renewable energy sources. We looked at energy efficiency and the potential for local renewable energy with two community partners: Dan Smith, the President of Integrated Energy Solutions, and Netaka White, the Executive Director of the Vermont Biofuels Association. By researching and considering geothermal energy technology, anaerobic digestion, and biofuels, we seek alternatives that diminish the vulnerability in Vermont agriculture to the dependence on fossil-fuel energy use and address the future of energy on farms.

Farmers are in a very powerful position to help with the world energy crisis. According to Dr. Heather Darby of UVM Extension, agriculture only accounts for 1% of direct energy usage in the United States, but has great potential to produce enough energy to be off the grid and to supply energy to others. In addition to on-farm efficiency measures such as appliance upgrades and new technologies, we see significant potential in energy transformation through renewable energy production on farms. By utilizing the cycles of on-farm nutrients and energy sources, energy costs can be considerably reduced or negated.

II. On-Farm Energy Efficiency and Use Reduction: Geothermal Milk Cooling Potential

a. Introduction

In Vermont, dairy farmers often use much outdated equipment that is very inefficient. The price of milk varies, thus creating unpredictable earnings for dairy farmers. The reality for most farmers' daily lives includes a significant amount of troubleshooting, maintenance and care for animals and land, with minimal payback. Despite outdated equipment being inefficient, the saying "if it ain't broke, don't fix it," or in this case, replace it, is evident, and farmers do not often prioritize purchasing more efficient equipment.

Through research, networking and interviews, we learned about ways in which dairies can reduce energy use on the farm and examined the potential of using geothermal technology to cool milk.

b. Energy Profile for a Typical Small Dairy Farm

According to Harvey Smith, a Vermont House legislator who grew up on a dairy farm, 50% of the cow dairies in Vermont are conventional, and 16% are organic (Smith, 2006). In 2003, there were 148,000 dairy cows in the state of Vermont, each of which produced an average of 17,431 pounds of milk (Vermont's Dairy Facts, 2003). Agriculture dairies with fewer than 150 cows produce more than 60% of the milk in Vermont. Energy costs, including those for chemicals, hauling manure and milk, fertilizers, and utilities, can claim 20% of the annual value of milk sold per cow on a farm. Approximately 40% of this energy comes from fuel used to haul manure and transport livestock, while the other 60% is electrical energy used mostly in the barn (Rogers, 2005).

Of these energy costs, there are fixed costs (costs that must be expended to produce a product) and variable costs (those which may be changed and will affect profit but not productivity). Utilities are the one area where small dairy farms can easily manipulate variable costs to increase their profit (Figure 1).

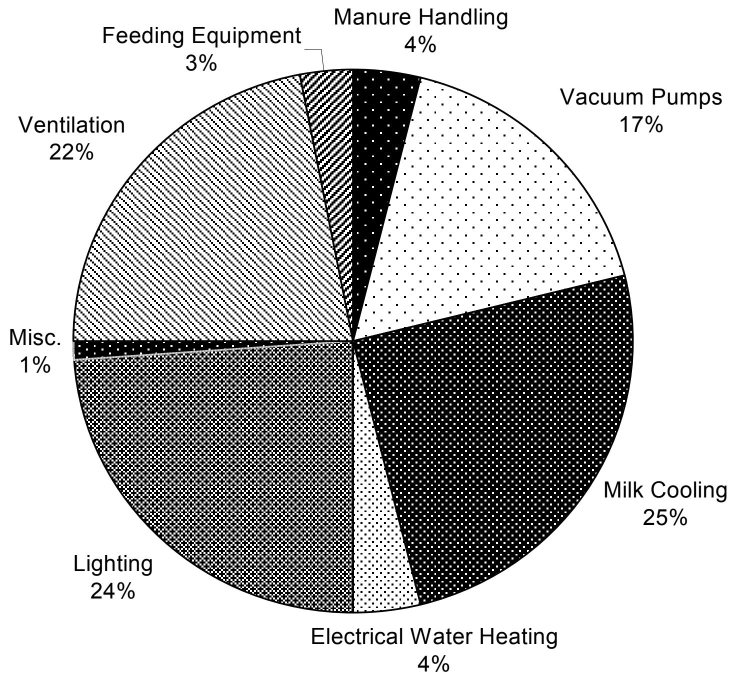

Figure 1. Electric energy use for 32 dairy farms in New York (Ludington and Johnson 2003).

Tiestall barns are the preferred milking method on small dairy farms. Tiestall barns have a milk pipeline running over each stall, and the farmer moves milking equipment from cow to cow. A study in New York State showed that in tiestall barns with an average of 77 cows, 72,126 kWh was used annually, or 1,001.63 kWh per cow per year (Ludington and Johnson, 2003).

In the barn, milk cooling, vacuum pumps, and water heating are large contributors to energy use, and all have the potential to be more energy efficient using new technologies. Conventional vacuum pumps which carry milk from the cow to the bulk tank waste energy because they operate at full speed regardless of need. To reduce the energy impact of vacuum pumps, variable speed pumps can be installed, and may reduce energy consumption of this equipment by almost 70%. This saves energy by pumping only when needed to meet the varying flow of milk from the cows. An investment in a variable speed pump can pay for itself in less than 2 years for dairies milking three times

a day, but would pay for itself in time even with less intensive farm operation. This technology has been cited as having the largest potential energy savings for dairy farms in the Northeast (Ludington and Johnson, 2003), and is being used frequently in newer dairies.

Another way in which energy use can be reduced in the barn is by amending the old, bulk tank refrigeration methods that are typically used in dairies. Bulk tanks usually consist of two stainless steel tanks, one inside the other, between which are an insulating foam layer and heat exchange coils through which refrigerant is passed. Refrigerant is a substance, such as ammonia, which evaporates at a very low temperature. Evaporating liquids pull heat with them, thus a substance that can evaporate at -27° F will create freezing temperatures (Brain, 2006). Conventionally, milk is put directly into the bulk tank after leaving the cow at a temperature of 98° F. Refrigerating a bulk tank holding hundreds of gallons of warm milk, however, is extremely energy intensive. One way this has been made more efficient is by pre-cooling the milk using a plate pre-cooler. In this system, cool well water is passed next to the milk, cooling it 30 degrees or more before it enters the bulk tank to be refrigerated the remaining 30 degrees (Wisconsin Public Service Corporation, Figure 2). This may decrease dairy electricity use by 15%. Variable speed pumps also may increase the efficiency of pre-coolers by providing a uniform flow.

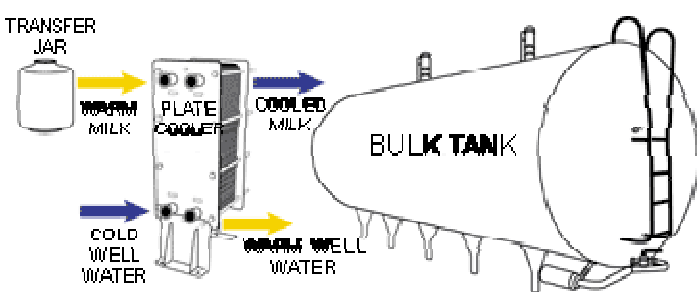

Figure 2. The general function of a plate milk pre-cooler is shown. Note that a byproduct is warm water, which may be returned to the well or used to clean milking equipment after being heated further (Flex Your Power, 2006).

Another way the cooling process can be made more efficient is by creating a refrigeration process that uses less energy. Figure 3 illustrates how conventional systems have used conventional refrigeration, in which a refrigerant in a vapor state (light blue) is passed through a compressor (B) where it gains heat (orange) and liquefies (purple). When the refrigerant is passed into a low pressure area (C), it immediately boils off the excess heat and passes very cold vapor into the refrigeration unit. This vapor again cycles into the compressor and the cycle starts again. Note that in a bulk tank, the light blue coils in the diagram are what are running between the two stainless steel layers (Figure 3).

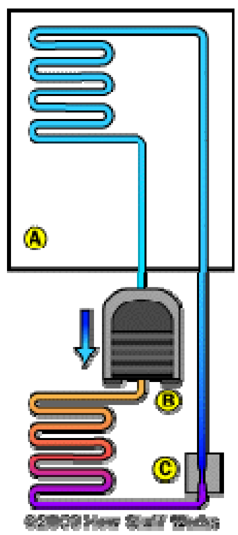

Figure 3. A simple diagram showing the components of a refrigerator (home.howstuffworks.com).

There have been several improvements to this traditional form of refrigeration. One is known as an air-source heat pump. In this system, an additional feature is added to the traditional refrigeration unit which uses air to absorb some heat from the refrigerant in the purple stage (Figure 3), then deposits this heat, usually in a building. This saves energy because the excess heat released by the refrigerant is harnessed and used for other purposes. Air-source heat pumps have not been applied widely on dairy farms as a method of cooling milk.

The most recent advance in heat pump technology uses the earth as either a heat source or a heat sink in assisting a refrigeration system. This is known as geothermal, or ground source heat pump, technology. Geothermal heating of water and chilling of milk are methods that could be beneficial for any size farm to offset energy demands. First, it is important to understand geothermal systems (Lund, 2001).

c. Geothermal Heating and Cooling

Nearly everywhere in the United States, the upper 10 feet of the Earth's surface maintains a constant temperature between 45 and 60° F, despite drastic seasonal changes. Since it is far less energy intensive to move heat than to create it, harnessing the heat that is ever-present in the ground is very efficient. Conversely, the ground can be used to absorb the heat found above ground if a cooling effect is desired. Though we should mention, the cooling mode energy is often not considered geothermal, since it consists of rejecting heat to the ground. It is replacing other forms of energy, however, so is considered in fossil fuel and greenhouse gases emissions savings.

Geothermal heat pumps, or ground source heat pumps (GSHPs), are electrically powered systems that tap the stored solar energy of the earth. GSHPs can reduce energy use by 23% to 44% compared to advanced air-source heat pumps, and by 63% to 72% compared to electric resistance heating and standard air-conditioning (Department of Energy, 1998:4). When comparing heating systems, safety, installation cost, operating costs, and maintenance costs must also be considered (Geothermal Heat Pump Consortium, 2003; Figure 4).

Compare	Safety	Installation Cost	Operating Cost	Maintenance Cost	Life-Cycle Cost
Combustion-based	A Concern	Moderate	Moderate	High	Moderate
Heat pump	Excellent	Moderate	Moderate	Moderate	Moderate
Ground Source	Excellent	High	Low	Low	Low

Figure 4. A comparison of various types of central heating systems.

The typical method for heating a home electrically is through resistance heating, which is found in radiant floor heating, baseboard heaters, and portable space heaters. It usually involves a metal heating element that converts electrical energy into heat energy and passes this heat into the air. Combustion systems are also used, which involve burning fuel to make heat. These are examples of *creating* heat. Air-source heat pumps (which pull heat out of the air, condense it, and emit it elsewhere depending on need) are about 1.5 to 3 times more efficient than resistance heating alone, because they *move* heat. Since the 1970s, operating efficiency has improved to make air-source heat pump operating costs generally competitive with combustion-based and resistance heating systems. Furthermore, air-source heat pumps can be reversed to have a cooling effect as well.

Ground source heat pump systems are comprised of pipes buried in the ground near a building, a heat exchanger, and ductwork into the building (Figure 4b). The heating process shown here can be reversed and made into a cooling process using the reversing valve (A), which simply changes the direction of refrigerant flow. These pipes are used along with an indoor unit containing refrigerant to provide a wide range of temperatures. Ground source heat pumps can be categorized as having closed or open loops, and those loops can be installed in three ways: horizontally, vertically, or in a pond/lake (Figure 5).

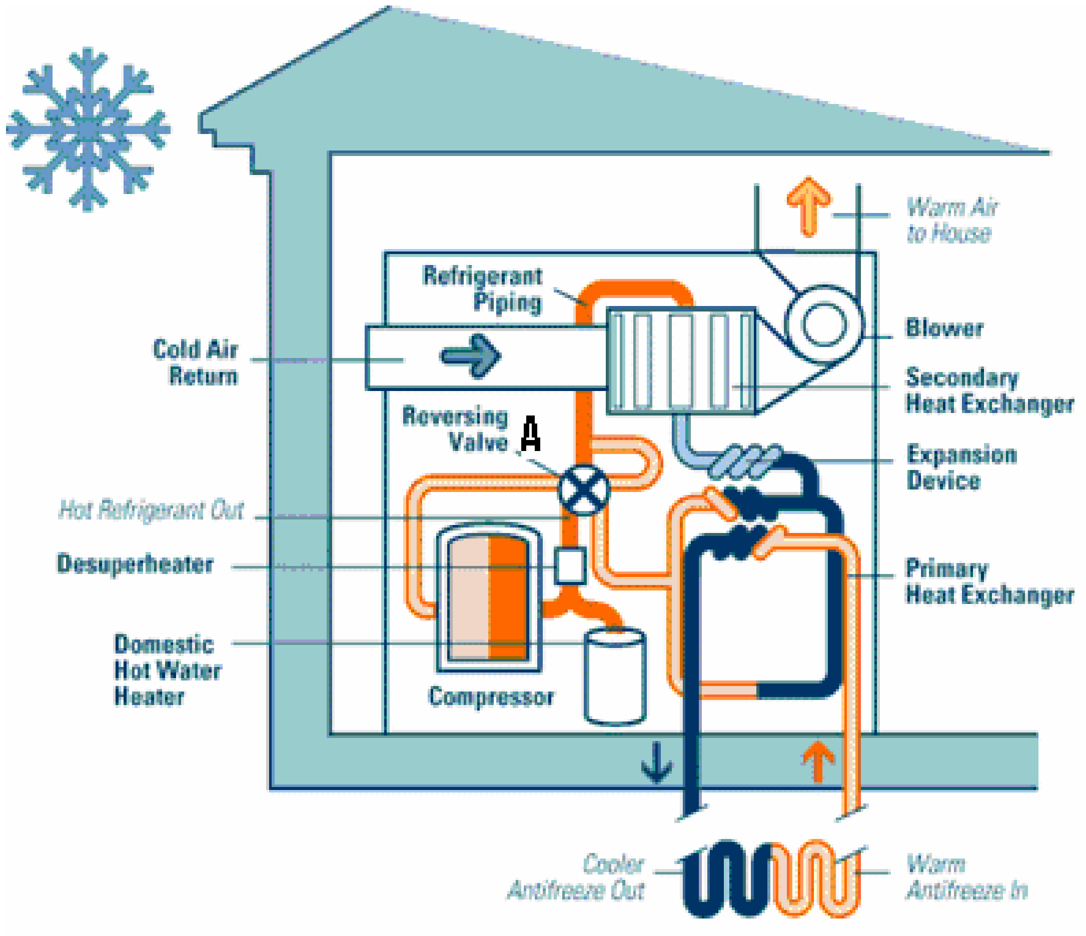

Figure 4b. A cross-section diagram illustrating the heat pump system (Office of Energy Efficiency, 2006).

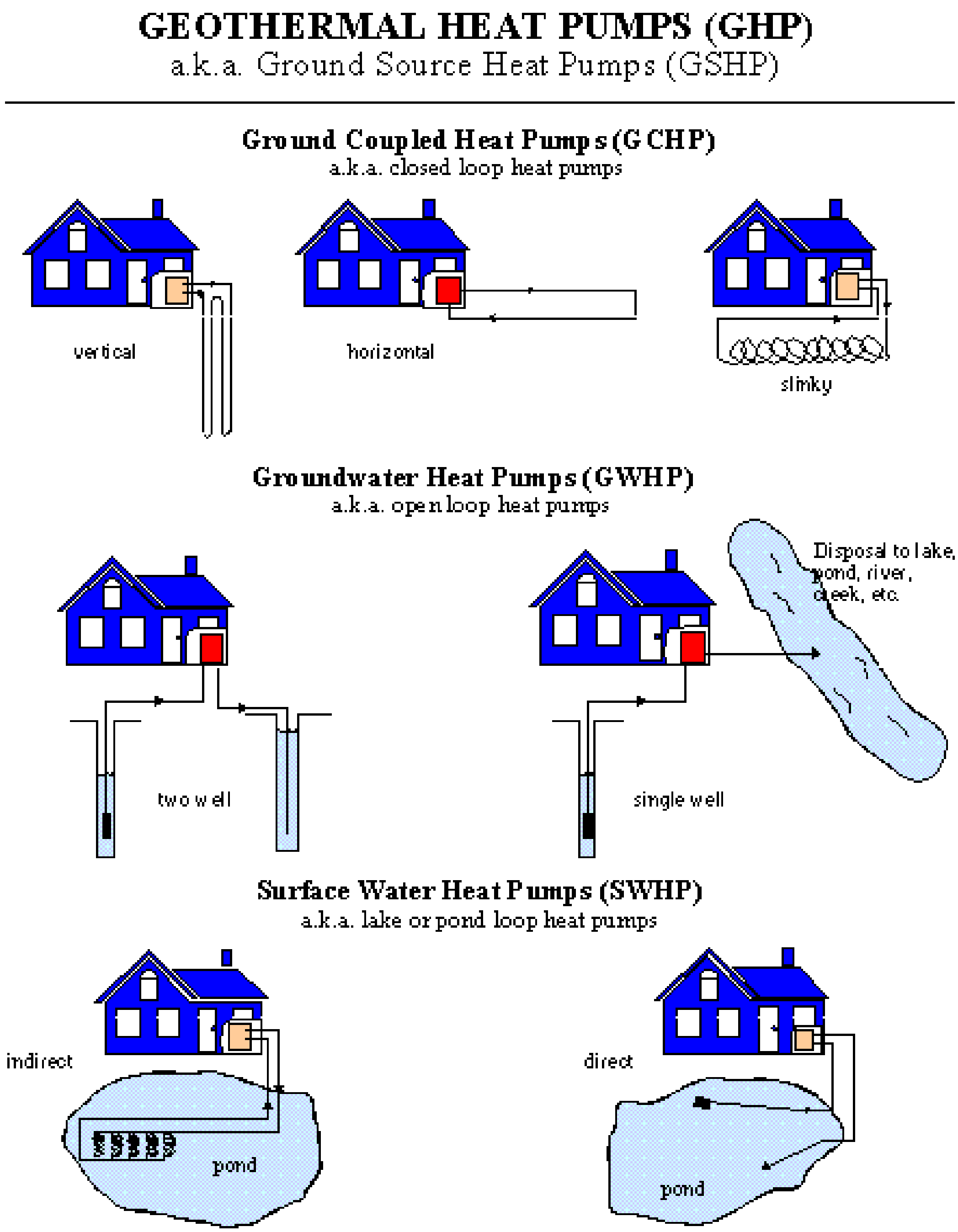

Figure 5. This figure graphically summarizes the different types of geothermal heat pumps available (Geo-Heat Center, 2005).

In a home, a closed loop system circulates water or antifreeze solution through plastic pipes buried beneath the earth's surface. During the winter, the fluid collects heat from the earth and carries it through the system and into the building. During the summer, the system reverses itself to cool the building by pulling heat from the building, carrying it through the system and placing it in the ground. Using a refrigerant and a compressor in conjunction with the heat pump, it can create temperatures much warmer or much cooler than the ground temperature while still using the earth as a heat source or sink. This process creates free hot water in the summer and delivers substantial hot water savings in the winter. Open loop systems operate on the same principle as closed loop systems and can be installed where an adequate supply of water is available and open discharge is feasible, although antifreeze cannot be used. Benefits similar to the closed loop system will be gained.

There are many benefits of using geothermal energy on a broader scale. Geothermal heat pumps are among the most energy- and cost-efficient heating and cooling systems available. Ground source heat pumps can be installed to tap the Earth's energy almost anywhere. Geothermal energy is available for 24 hours a day, every day, and is a clean, local source of energy that can be extracted without burning fossil fuels. Furthermore, they do not combust and therefore don't create indoor pollutants.

Ground source heat pumps use less electricity and produce fewer emissions than conventional systems, reducing air and water pollution. Although their installation cost is higher due to the required underground connections for heat transfer to and from the earth, ground source heat pump systems provide low operating and maintenance costs and greater efficiency resulting in significant savings in utility expenditures. Approximately 500,000 geothermal heat pumps are being used today for heating and cooling throughout the United States in residential, commercial, and government buildings (Department of Energy, 1998). Projections for the future indicate the growth rate will increase about 12% annually so that by 2010 an estimated 140,000 new units would be installed in that year (Lund, 2001).

Strategies similar to ground source heat pump technologies have been applied to enhance the efficiency of dairy farm operation on many of Vermont's farms. According to Dan Scruton of the Vermont Agency of Agriculture, "two-thirds have hot water heaters

that run off their refrigeration system. [Farmers are taking water from the heat cycle] and instead of putting it in the ground, they're putting it into a tank and using the water to wash their equipment" (Dan Scruton, personal communication). It is clear that the benefits of geothermal technology for efficient heating and cooling are increasingly widespread and utilized, even if the majority of the farmers themselves do not call the technology they are using "geothermal."

d. Geothermal Cooling Application to Vermont Dairy Farms

While "most of the farms in Vermont are already using geothermal technology" (Dan Scruton, personal communication), few—if any—are using geothermal for refrigeration. Right after leaving the cow, milk's temperature is around 98° F; it needs to be cooled within two hours of milking to about 38° F. Since milk is 40 to 50 degrees warmer than the constant temperature of the ground, well water or water circulated through the ground and passed by the milk in an adjacent pipe will absorb heat from the milk, cooling the milk substantially before it enters a bulk tank. This is the most basic application of geothermal in milk cooling, and is the general technology of plate coolers. Dan Scruton reports that about half of the farms in Vermont are using plate coolers, "which *are* geothermal because they are taking water from their wells and running it through a plate cooler to pre-cool milk" (Dan Scruton, personal communication).

However, it could be taken a step further by installing a ground source heat pump to perform the refrigeration needed in the bulk tank. As was mentioned earlier, air-source heat pumps combine heat exchange with the air with traditional refrigeration to increase efficiency. Similarly, ground source heat pumps use water as the heat exchanger, an even more efficient system since water has a much higher specific heat. In fact, 3,472 times more heat can be stored in a cubic foot of water than a cubic foot of air (Geothermal Heat Pump Energy, 2006). Furthermore, using the constant temperature of the earth to extract or absorb heat means the system does not have to compensate for drastic fluctuations in temperature, as are common in outdoor air (especially in places like Vermont, which ranges from 100 degrees to -30 degrees) also improving efficiency. For example, it would take more energy to have 90 degree air absorb heat than it would 60 degree earth. This explains why ground source heat pumps are up to 50% more efficient than air-

source heat pumps. Note how the ground source heat pump functions similarly to an air source refrigeration system (Figure 6).

Dairies may be particularly well-equipped for this type of technology because they must have a substantial water source available simply to operate, and water-based geothermal therefore is a strong possibility. Because there are a multitude of different ways to install geothermal pipes in the ground, dairies need not be limited by property boundaries or locations of other buildings on the property. Furthermore, as geothermal systems have very little above-ground equipment (about the size of a refrigerator), the limits of barn space are not an obstacle.

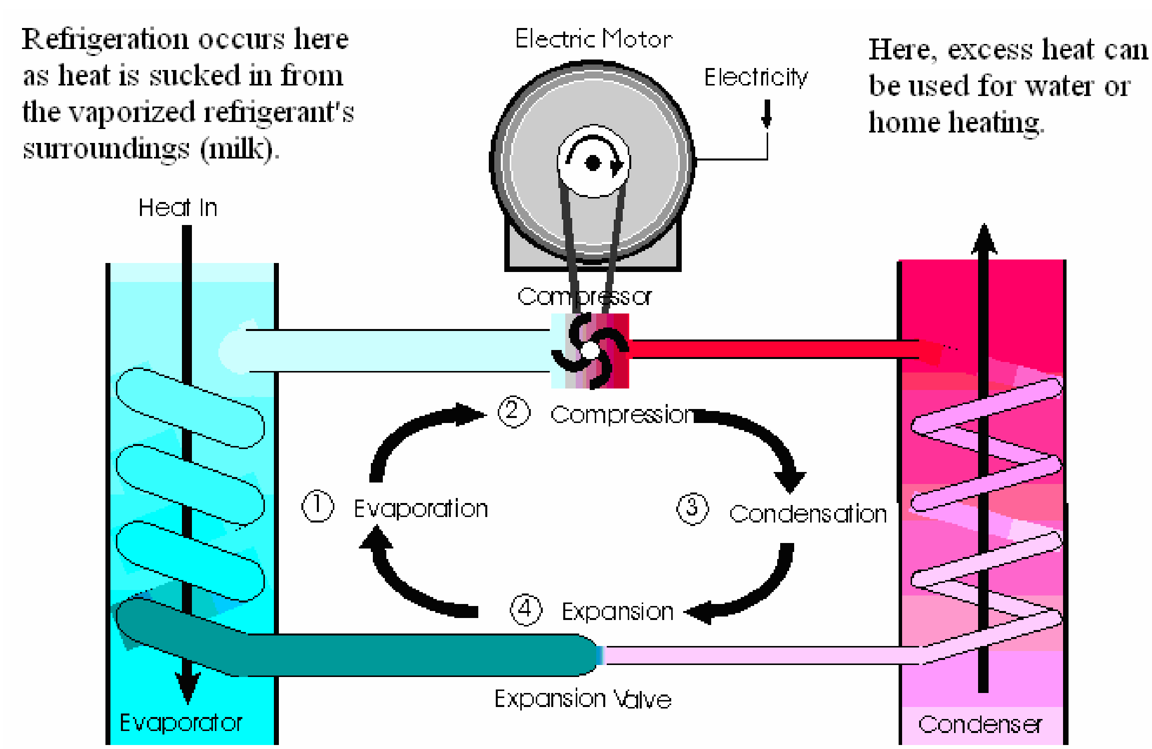

Figure 6. This diagram depicts a basic water-to-water heat exchanger. This heat exchange works just like a refrigerator; with a hot side and a cold side (New England Ground Source).

e. Costs

Although installers of geothermal systems are enthusiastic about the potential of geothermal, and although they are confident as to the payback potential of installing such a system, it is very difficult to acquire actual quotes for how much the system might cost to set up. Of course, costs fluctuate greatly depending on the type of system that is desired, the availability of space and groundwater, and the heating or cooling needs. Nonetheless, there seems to be a standard range that one can expect when considering such a system.

Ground source heat pumps themselves, that is, the actual indoor unit plus any underground loop system involved, cost between $1,000 and $2,000 per ton of capacity. A ton is equivalent to 12,000 BTUs, and most homes require a 3-ton capacity. When you factor in other components, like heat or cooling distribution and installation cost, the price jumps to $4,000 per ton, or more. Andrew Chaisson, who works for the Geoheat Center at the Oregon Institute of Technology, estimates that an entire system will cost between $10,000 and $25,000 to heat and cool an average home (Expert Village, 2006). Still, many are convinced that the energy savings will pay for themselves with time, the estimate usually between 2 and 10 years (Geothermal Heat Pumps, 2006).

Therefore, it must be determined how many BTUs of capacity a farm would need to power the refrigeration of a bulk tank. Furthermore, if the farm wanted to harness the byproduct of heat and use it to warm water or heat their home or barn, the BTU capacity would almost certainly have to be higher. Also, it has yet to be determined whether the typically quoted efficiency of geothermal is applicable to the same technology when used for refrigeration. According to Dan Woodring, correspondent at Sunteq Geo Distributors, the real savings in geothermal are in heating, not cooling, and although this type of system would lead to large energy savings, it would not have a fast enough payback to justify initial costs. A system that includes heating the house and water as well, he says,

> "would be a complex system to design and install but it could be done. It would need to be a water to water system. In the winter it would take heat from the house to chill the water pumped through a heat exchanger in the milk tank. The water flow would have to be controlled to keep the water cold enough to chill the milk. Controls would need to be added to deal with excess heat or lack of a need for heat. You are probably looking at

> $20,000 to $30,000 depending on who does the actual installation work. Equipment and materials cost would be on the order of $12,000 to $14,000" (Dan Woodring, personal communication).

Unless Vermont is able to devise a fund to encourage geothermal initiatives on farms, the installation of geothermal for cooling milk may not be realistic given the economic inflexibility of most farmers.

f. Funding

While there is no grant program or funding incentive for geothermal systems in Vermont, Public Service of New Hampshire, or PSNH, has a grant program that goes through the procedures for joining initiatives for installing geothermal energy systems in Energy Star homes (Public Service of New Hampshire). This program could easily be modeled and presented for consideration to the Vermont legislature.

Vermont has recently encouraged other energy efficient technologies and offered incentive money. In August 2006, the Vermont Department of Public Service announced a nearly $1 million fund to provide as incentives for wind and solar energy installations (Vermond Department of Public Service, 2006). In the future, it would be possible to earmark a portion of this type of money for farm energy advances, including geothermal technology.

If a farmer were motivated to install this technology even without state or federal funding, banks might be amenable to funding a geothermal project because of the savings in energy costs it would lead to, thereby leaving the farmer with surplus money each month to pay off loans.

g. Feasibility for Small Dairy Farms in Vermont

Based on our research on small-farm electricity use, geothermal technology does offer an alternative for significant efficiency gains and independence from fossil fuel use. A system could be successful if 1) the owner/operator realized the benefits geothermal technology has to offer and wanted to make it work, 2) the owner/operator had some mechanical knowledge and ability and had access to technical support, 3) the

designer/builder built systems that were compatible with farm operation, and 4) the owner/operator increased the profitability of geothermal systems by connecting it to another local alternative energy system such as anaerobic digestion or biofuel.

However, geothermal is currently an under-funded and under-researched system in the United States. The technology has met with much success when applied to heating and cooling buildings like schools, resorts, medical facilities, condos and even a US Army base (New England Ground Source #2). While geothermal heat pump systems are widespread in residential and commercial use around the United States, those involved in the agricultural sector have barely experimented with this technology, if at all. It will be impossible to estimate costs and savings for a dairy without any direct case studies to reference since a refrigeration system is so different from a heating and cooling system. Options need to be evaluated on a case-by-case basis depending on the size of the farm and their local water source options.

Approximately 15 to 30 percent of a dairy's electricity load is used to cool milk. Geothermal systems are a proven, cost-effective way to increase energy efficiency and decrease electricity use. If refrigeration is combined with home heating or water heating, the efficiency may be increased, and a geothermal system may be a feasible option. Further research and development is needed for the realities of cost, implementation and maintenance to be understood. Overall, geothermal technology used on dairies will not be feasible until there is funding available for experimenting with these systems.

h. Recommendations

We recommend the USDA's renewable energy grant source and the Clean Energy Development Fund for Vermont fund pilot projects for geothermal system installation on dairy farms. Implementation and evaluation could be done through a state-level organization focused on farm energy, such as Efficiency Vermont (www.efficiencyvermont.com) or AgRefresh (www.agrefresh.org). The best way to determine the feasibility will be through pilot projects, especially on small farms with older buildings and equipment. We recommend prioritizing funding for geothermal systems as a primary method for increasing energy efficiency on farms.

To further pursue the possibility of using geothermal heat pumps on dairies, we recommend that Integrated Energy Solutions acquire energy bills from some small dairies in Vermont and use their exact energy consumption to better evaluate the potential savings that a geothermal system would provide (see example in Appendix B). If the energy savings and startup costs of a geothermal system seem reasonable for a small farm, steps should be taken to collaborate with other local organizations and find funding sources to implement a pilot project. Only through such a project could the true net energy savings be evaluated and compared to those of other renewable energy systems on farms. Finally, only with such an evaluation would farmers be interested in considering this type of system.

This section discussed the reduction of energy use on a farm. Another way farmers could reduce their energy costs would be to produce energy on their farm from available resources. Continuing to look at small dairy farms, the next section will discuss the feasibility of using manure for on-farm energy generation through anaerobic digestion.

III. Anaerobic Manure Digestion for Methane-Based Electricity and Process Byproducts

a. Introduction

Dairy farms play a significant role in Vermont's local economies. In 2002, milk sales by Vermont dairies totaled $400 million (VDAFM, 2003). However, these farms are facing the burdens of increasing economic, public, regulatory, and other pressures, which are forcing more and more of Vermont's farmers out of business (Fehrs, 2000). In fact, the number of dairy farms in Vermont has decreased more than three-fold (from 6,994 farms to just 1,970) over the past four decades (Fehrs, 2000). One way that dairy farms can address their financial predicament is by reducing their costs. Energy is a substantial component of dairy farm operating costs, with energy usage claiming 12% of the value of milk sold by the conventional small dairy (Rogers, 2005). Farm self-sufficiency and sustainability can be enhanced through adoption of better on-farm energy practices. Energy expenditures can be reduced by first investing in efficiency measures, such as the geothermal technology discussed in the previous report section. Some dairies, even small ones, may also find it advantageous and cost-effective to produce their own energy. This may be done via wind turbine or solar panel installation, or by anaerobic digestion of farm wastes or planting of biofuels crops. Anaerobic digestion is the topic of this section; biofuels will be explored in the next.

Anaerobic digestion (AD) provides a number of potential economic benefits for Vermont's dairy farms. ADs allow farmers to reduce their energy expenditures, through generation of their own electricity, and create multiple new sources of potential income from the non-electricity byproducts (Fehrs, 2000). In addition to the financial constraints burdening small farms, dairy farms and other confined animal feedlots have fallen under the scrutiny of increased environmental regulations. Manure management is necessary to control negative environmental effects such as ambient odors and nutrient and pathogen runoff. One way Vermont farmers can improve manure management to meet these environmental regulations is through the use of ADs (Fehrs, 2000). Community sustainability and environmental quality are further increased by AD operation through the greenhouse gas reductions associated with methane capture and replacement of fossil

fuel derived energy and by the provision of a stable, renewable, local energy resource (Fehrs, 2000).

In Vermont, 70% of the roughly 1,400 working dairy farms have fewer than 100 cows (Smith, personal communication; Fehrs, 2000; VDAFM, 2003). These small-scale farm operations have limited profit margins and little capital. These small farms would significantly benefit from the revenues generated by an AD, but their financial constraints make it difficult to install capital-intensive AD systems. For this reason, we have researched the potential for manure-based digestion systems to be viable, both economically and technologically, for this large segment of Vermont's dairy farmers. This study has been undertaken in conjunction with statewide efforts to increase energy efficiency and production options on Vermont's farms. Much has been done recently to spur development in renewable energy around the state, including through farm energy projects and research (Vermont Environmental Consortium's Farm Energy Handbook; Vermont Methane Pilot Project). It is in collaboration with Dan Smith of Integrated Energy Solutions, that we focus on the future for the application of AD systems at small dairies.

Anaerobic digestion is an ancient technology, its use dating back as far as the 10^{th} century BC when Assyrians utilized the technology to heat water for their baths (Scruton, 1999). The basic components of any digester are: a digester tank, a gas-handling system, a gas use device, and a manure storage tank to hold the treated effluent until land-applied (EPA, 2006). Solids separators are also common in dairy applications. An AD works by harnessing the natural process of anaerobic decomposition of organic 'wastes,' such as manure, by bacteria in an enclosed, airtight tank or lagoon to produce biogas (mostly methane), heat, and solid and liquid organic materials. These end products have substantial market value: biogas can be burned to produce electricity which can be utilized on-farm and excess sold to the grid; the digester's liquid byproduct is a reduced-odor fertilizer, with fewer pathogens, weed seeds, and amounts of phosphorus; the solid manure byproduct also has the same purified properties as a result of the digestion process. These solids can be used on-farm as a soil amendment or sold off farm as fertilizer, as is done by the Foster Brothers Farm in Middlebury, Vermont. Alternatively, the solid byproduct can be used on-farm or sold as bedding for cows or other livestock.

The heat byproduct can be used to heat space, such as a greenhouse or barn; water for cleaning purposes; or even to process cheese, as is done at Nordic Farms in Shelburne, Vermont.

There are a number of different digester designs available today, with the three most common being: 1) covered lagoons, 2) plug-flow, and 3) complete mix (Burke, 2001; Scruton, 1999; Nelson and Lamb, 2002). Covered lagoons are not suitable for Vermont, because of the cool temperatures experienced much of the year. Thus, plug-flow and complete mix systems are the most applicable system models feasible in Vermont (Scruton, 1999). These types of systems have a history of varying degrees of success in operation the United States (Burke, 2001; Lusk, 1998; Scruton, 1999). As of 1998, the failure rates for complete-mix and plug-flow digesters in the United States were a staggering 71% and 63%, respectively (Lusk, 1998). However, since 1984 the reliability of digesters has improved dramatically as a result of simpler, more refined digester designs (Lusk, 1998). Given these advances, ADs are less of a risk today than they were 30 years ago. Now many more digesters are being constructed, especially in Vermont, which is leading the boom in digester construction.

b. Methodology

The available dairy farm AD literature focuses on medium to large establishments (those with more than 500 cows), as conventional wisdom dictates a 300-cow or higher threshold for AD economic viability (Nelson and Lamb, 2002; EPA 1; EPA 2). To guide our project, we created a list of questions that need to be answered to determine AD feasibility for smaller Vermont dairies; these are compiled in Appendix C. We have been able to answer many of these, but those left unanswered should guide future work to develop AD viability in Vermont.

To assess the limitations of this supposed scale barrier, we have contacted those leading the effort to extend the technology to smaller farms. Through interviews of anaerobic digestion system designers, commercial energy program workers and local digester operators, we have been able to supplement the conventional wisdom and literature with an assessment of the future prospects for ADs on small farms. Additionally, we use interviews with a small subset of local dairy farmers to assess their technological

and financial potential for successful AD implementation, as well as their willingness to undertake the risks and commitment involved with planning, managing and operating an AD. As an extension of our research and interviews, we have developed a methane digester feasibility survey (Appendix D) for future use in cooperative assessments with Vermont farmers to gauge the AD feasibility potential of their farm and of farmer willingness to develop an AD system. This assessment framework looks at the farm's current number of cows, manure and cow management practices, operating costs, financial resources, technical knowledge, and other relevant factors. A basic initial assessment framework suggested by AgStar, the EPA's AD program, utilizes the chart below (Figure 7) to translate one's manure properties into the potential best system design to consider (EPA, 2002). Our assessment builds on this basic idea to help the small dairy farmer and AD consultant better assess system potential, given the individual farm's characteristics, constraints, and opportunities.

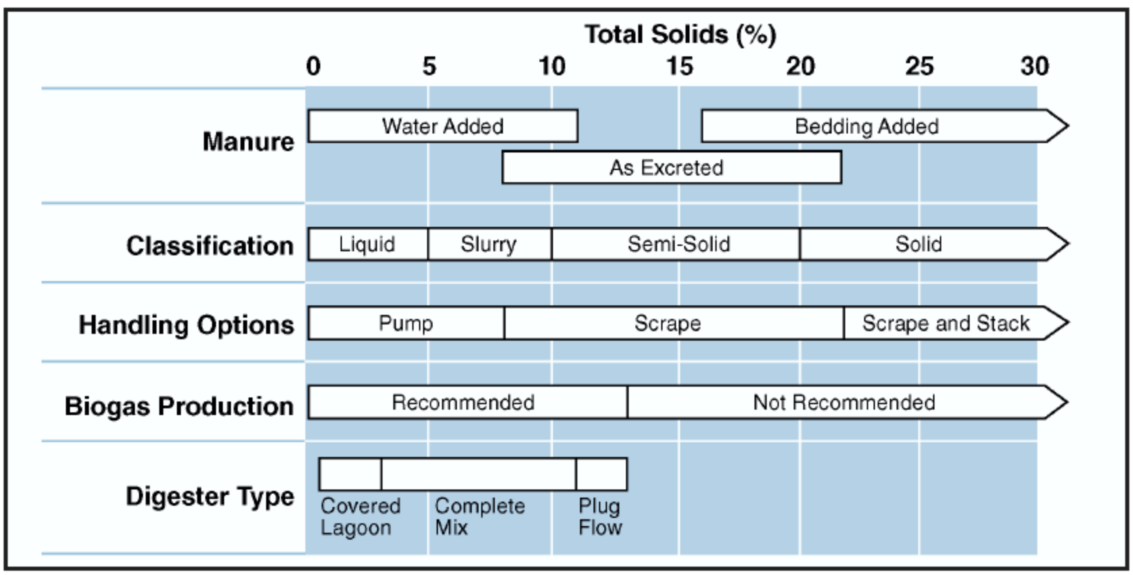

Figure 7. A basic framework for the assessment of best AD system design on a given farm (EPA, 2002).

c. Findings and Results

ADs have been used extensively around the world. Six to eight million low-cost anaerobic digestion systems have been successfully utilized in small family farm operations in the developing world to provide families with a renewable, local source of the majority of the gas necessary to meet their cooking needs (Lusk, 1998; Rutamu, 1999;

Xuan An, *et al.*, 1998; van Nes, 2006). In the United States and other developed countries, these systems do not make economic sense, despite the low building and design cost, because of the existing infrastructure, transportation systems, and low costs for heating (Scruton, personal communication). In China and India, the current trend is towards using larger, more sophisticated systems to generate electricity (Lusk, 1998). In Europe, ADs are a widely used technology, with over 2,000 systems in operation, including 250 that were built in the last five years in Germany alone (Monnett, 2003; Lusk, 1998; Nelson and Lamb, 2002).

Our literature search and contacts with professionals in Vermont has yielded two significant recent studies that focus on the feasibility of anaerobic digestion at small-scale dairies, as well as significant supplemental information specific to Vermont. The conventional wisdom regarding dairy farm anaerobic digestion of manure wastes holds that it is not economically viable to operate an AD on farms with fewer than 300 cows (Nelson and Lamb, 2002; EPA 1; EPA 2). Given the size profile of Vermont's dairies, assessment of the viability of small-scale anaerobic digestion operations is essential before a more widespread development of methane digesters in Vermont can occur.

Dairy farming is not an easy or highly lucrative business, as indicated by the steady decline of operating dairies in Vermont since the 1960s (Fehrs, 2000). Installation of an anaerobic digester has a high initial cost, but it can decrease farm-operating expenses and increase revenues by producing energy and marketable byproducts. ADs can be used to generate one's own farm electricity needs by burning the digester-produced biogas to power a generator. If all the available manure in Vermont were fed to digestion systems, a total of 30 megawatts of electricity per hour would be produced, or

roughly 18 kW/per farm/per hour[1] (Fehrs, 2000). The Fehrs (2000) study includes all farm wastes as feedstock, of which 96% is manure. The average on-farm energy demand peaks at 7 am and 6 pm at about 15 kW, with an average of approximately 8.4 kW/per hour over the course of a day (Fehrs, 2000). It appears that Vermont farms have the potential to generate enough electricity to power all their electric demands and have a large surplus of energy that can be supplied to the grid (Fehrs, 2000). If the average energy demand for all Vermont farms is approximately 11.76 MW/per hour, the surplus of energy generated from Vermont farms would be 18.24 MW/per hour. This is enough energy to power over 6,080 Vermont homes in addition to meeting Vermont's dairy farm energy demands (Searsburg, 2006).

Currently, anaerobic digestion systems in the United States are concentrated on large farms of 500-4000 cattle. Digestion systems must be designed fairly specifically to each farm and in addition to high capital construction and engineering costs, there can be significant management and operation costs and labor requirements. Maintenance and operation costs typically run about \$0.02-0.03 / kWh generated (Scruton, personal communication). All of this combines to make ADs risky ventures that are financially out of reach for most farmers, despite grant opportunities (EPA 1; EPA 2).

Aashish Mehta and Philip Goodrich have each recently conducted comprehensive technological and economic feasibility studies of small (less than 300 cow) digester systems. Mehta created a cost-benefit analysis model of anaerobic digestion systems based on electricity rate structure, farm energy load curves, and grid connection for 30, 60, 200 and 400-cow operations. Mehta cites capital cost estimates varying from \$660 to

[1] Throughout this report, we will use the kilowatt hour (kWh) and megawatt (MW) as our units for measuring energy (1MW = 1000 kW). Domestic energy bills typically use the kWh as the measure of energy use, thus it is a familiar unit to many homeowners. This unit is only used in describing moderate amounts of energy, therefore requiring further explanation for the purposes of our project. "Energy" describes power over time. The definition of a kWh is the amount of energy from one kW of power running for one hour. Most energy in the United States is expressed in joules, and one kWh is equivalent to 3,600,000 joules (whatis.techtarget.com). A kW is 1,000 watts, thus one kWh is equivalent to leaving a 100 watt light bulb on for 10 hours. A clothes dryer has the ability to use 5,000 watts, so running a dryer for one hour would consume 5 kWh.

$1000 per cow. Although this would indicate a $66,000-$100,000 start up bill for a 100-cow farm, it is significantly lower than other estimations for such small operations.

Temperature is a significant factor in Mehta's model of net energy return. Most anaerobic digestion systems utilize mesophilic bacteria to break down the waste materials to produce biogas. Mesophilic bacteria perform at their optimum rate in temperatures of 95-98˚ Fahrenheit. Additionally, temperature maintenance affects the quantity of moisture in the biogas (Burke, 2001). Since net energy return influences the economic viability of digestion systems, temperature is an important factor to consider in digester feasibility in the relatively cold climate of Vermont. Temperature considerations will influence digester design options, as lagoon systems have been ruled out in Vermont (Scruton, 1999).

Additionally, Mehta's model investigates the influence of manure loading rates and the properties of the manure upon addition to the system. Given the constant manure loading requirement of an AD, manure management practices are an important consideration in determining digester feasibility on a given farm. Many small dairies, especially those with organic certification, seek to have their cows out at pasture as much as is possible. Such a farm may then only have their cattle in a barn during milking, representing only a few hours of the cow's day. While this is advantageous for the cattle, it presents a problem for manure collection to feed a digester system. All manure excreted while out at pasture cannot be fed to the system. Thus, the small farms that may benefit most from their own energy production (as a way to reduce costs), are at a disadvantage as compared to large industrial farms where cows never leave their stall. While cows tend to excrete waste at a disproportionately high rate while milking and feeding, their limited time indoors (approximately 6 hours) in the warmer months (Mark Russell, personal communication) may still limit the ability of a farmer to continuously feed the necessary amount of manure into their AD. Additionally, the premium gained for organic certification may outweigh the energy and byproduct benefits of AD installation. Pasture time and AD viability are not necessarily mutually exclusive, although pasture time may be required to be reduced or one could convert to paved "pasture," from which manure could be reclaimed.

Mehta's models find that it is not viable to operate an AD system to generate electricity on farms having fewer than 60 cows, given that the hourly energy demand of such small farms would exceed the "electric power potential" of the digester. This is a significant threshold limiting the potential viability of systems in Vermont, where such small dairies exist. This may provide extra incentive for the creation of a cooperative AD operation at a central farm with other small dairy neighbors to contribute to the necessary manure supply. However, 60 cows becomes the break-even point at which the average small farm could, theoretically, always satisfy its own operational energy demands through running an AD system. Beyond 60 cows, Mehta calculates that it is possible to generate excess electricity to sell to the grid if a net metering plan and appropriate pricing regimes are in place. The adoption of energy efficiency measures, such as geothermal milk cooling technology, would theoretically lower this threshold, making systems viable for even smaller farms.

Given the importance of electricity rate regimes and net metering capabilities in Mehta's analysis of small scale digestion viability, it is important for Vermont to have an electricity rate scheme that provides an incentive for farms to generate their own energy and that facilitates their provision of excess energy to the grid system. Such a sales incentive may be achieved through favorable rate schemes (which will depend on farm size, see Mehta, 2002), green energy pricing incentives (such as renewable energy credits), and grid connection assistance (to mitigate the expense of grid interconnection, which is estimated to cost about $700-1100 /kW, and an additional 30-70% in site preparation, installation and maintenance (CEC, 2002)). Through CVPS's CowPower program, the average small Vermont farm, paying residential energy rates, would face a rate regime in which they could sell digester generated renewable energy at a price *less* than they pay on their current electricity bills (residential rates are currently $0.114/kWh, whereas CVPS CowPower generators receive $0.107/kWh for their production). Given this scenario, Mehta's study indicates that the current pricing regime favors small farm digester systems and small cooperative digester operations in Vermont. In this scenario, farms will be inclined to dedicate as much energy as they can to offsetting their own electric costs. Smaller farms have larger energy bills per cow than do larger farms, so by offsetting these costs using their own energy they would save more money/per cow then

larger farms can. If the price at which one could sell was greater then the price at which you buy electricity, larger farms would be distinctly favored. Larger farms are able to make more electricity and would be able to be much more profitable than small farms by simply having a larger operation. The rate scheme in Vermont however, is positive for small farms.

Renewable energy credits provide a growing means by which the economic viability of any size AD system may be enhanced. RECs are a premium paid for the environmental attributes of the production of green, renewable energy. Premiums currently run at $0.04-0.06/kWh, financed by a significant and growing environmentally-minded electricity consumer population. A 100-cow farm producing the average net 1100kWh/cow/year (based on 4.8kWh/cow/day production less 700kWh/cow/year consumption as indicated in Mehta, 2002) could thus, earn an extra annual revenue stream of $4,400-6,600 from the sale of RECs.

The Goodrich study is a compilation of theoretical estimates of the viability of five different digester systems designs, analyzed on a net annual cost basis for a 100-cow dairy operation. Additionally, Goodrich investigates the potential for a digester cooperative in which 3-4 farms within a 2-mile radius of the central site, and a combined total of 1000-1200 head of cattle, would co-run a central digester. Goodrich finds a range of annual net costs from $64/ cow to a net benefit of $24/ cow. The average single farm system capital cost is $150,000 and the average annual benefits of the digester are $27,000. The study's cost calculations annualize system capital and engineering costs over ten years. Goodrich's analysis of single farm systems, however, does not include the addition of electricity generation machinery or the revenue potential of electricity, which will add $75,000-150,000 in capital and installation costs, but also has the potential to increase annual benefits through reduction in on-farm energy bills and through revenues generated from the sale of excess electricity to the grid. (The study focuses on a basic AD system in which waste heat and manure byproducts are the benefits.) The cooperative's capital costs (including an electricity generation system) were $550,000 with annual net benefit of $193,000 (which corresponds to a $38/cow benefit). With four equally-sized farms in the co-operative, this translates to an upfront cost of $137,500 per-farm and annual per farm benefits of $48,250. Such cost-sharing and benefit estimates indicate the

attractiveness of cooperative systems where spatial conditions are favorable. Thus, the cooperative set-up provides a potentially more viable system in which to utilize their farm wastes, but it is unclear what the maximum viable distance among partner farms may be to still allow for significant returns from the operation. Mark Russell, an Orwell, Vermont dairy operator, indicated that it costs him $50 per 10 cubic yard truck load of manure to collect, transport, and deposit his neighbors manure to his own manure storage facility, not including the cost of wear and tear on his truck (personal communication).

Given the high start-up costs, but significant potential for net benefit, even at the 100-cow level, the importance of creating financing and grant opportunities in order to make ADs possible becomes clear. Additionally, the cooperative system appears to be a potentially viable opportunity that may be well suited to Vermont's small dairy network, particularly in Addison and Franklin Counties where small dairies tend to be fairly close together. The sensitivity of farm data, however, prohibits a GIS analysis of farm dispersal in order to identify potential digester cooperative sites in Vermont.

In summary, Mehta (2002) finds a 60-cow minimum for the net energy viability of anaerobic digestion on the average farm. His study takes into account the energy costs per cow for dairy operation in relation to the maximum sustainable load possible on a per cow basis. The significant barrier to small-scale digester implementation is the substantial capital and engineering costs associated with designing and building these systems. Although Goodrich finds that certain system designs have a net positive annual return over 10 years, many small farms, despite a growing source of renewable energy grants, cannot obtain the necessary capital upfront or afford to wait out a ten year payback period. Additionally, as digester technology is relatively new, there is significant risk and day-to-day management hassle involved in an AD undertaking. These difficulties led to only one in six of California farms having ADs continuing their AD operations (Morse, *et al.,* 1996). This highlights the need for research and development to lead to technological improvements as well as for the development of an AD service industry.

Vermont provides an interesting case study for anaerobic digestion. Given that the state has historically favored putting its development resources into enhancing economic feasibility, as opposed to technological innovation (Scruton, personal communication), the state is in many ways a leader in the AD industry. In 2005, Vermont won 80% of the

USDA's AD financing grants (Scruton, personal communication). However, Vermont's AD systems still follow the national trend—they consist only of farms with more than 300 head. CVPS has contracts for four new systems to come on line in Vermont by the end of 2007 (Dunn, personal communication). Of these new systems, the average herd size is 733 cows and the average energy generation potential is 2,140,000 kWh/year. Additionally, some non-CVPS supported systems are scheduled to begin operation in the next year, with potentially one cooperative system among them (Scruton, personal communication).

Conversations with local energy and agriculture department professionals have provided us with a valuable, Vermont-specific supplement to the widely available literature. According to Dan Scruton (personal communication) of the Vermont Department of Agriculture, manure-based digestion systems may not represent the best opportunity for Vermont small farmers to utilize their farm wastes as an energy source. In his opinion, ADs that run solely on manure are not and will not be economically viable on a small-scale (under 200 cows) for the foreseeable future. Mr. Scruton believes that for digesters to be economically viable on these small farms, digester feedstocks will have to incorporate crops (or crop residues, including cellulosic materials) or processing wastes, such as whey, along with manure. Thus, Mr. Scruton believes that the future of economically viable ADs for Vermont farms lies in waste-based systems that utilize manure only as an additive, although it would still comprise approximately 50% of total feedstock. The use of cellulosic crop wastes, such as corn stover, in an AD system has a retention period six times that of a manure-based system (due to the difficulty of bacterial breakdown down of cellulosic material relative to manure), but produces multiple times the biogas on a per-cow basis. The increased retention time would raise capital costs, due to the need for a digester tank six times the size necessary for a purely manure-based system, but would reduce the number of cows necessary to have a viable operation. A cellulosic-based system would require approximately 1000 acres of crop waste per 100 cows to provide the optimal feedstock ratio for a 1 MW system (Scruton, personal communication). Cow manure has a lower energy potential in digestion than do crop wastes, since the cow has already utilized much of the energy in the material before excretion, but is necessary in the crop mix to provide the anaerobic bacteria needed for

decomposition. Vermont is well suited to the production of forage crops that may provide the cellulosic material for an AD operation. The state had over 350,000 acres of land in forage crops in 2002 (USDA, 2002).

In addition, Mr. Scruton sees promise in Vermont for a whey-based AD system. Whey is the liquid waste product of cheese manufacture and it can be used as a digester feedstock in combination with cow manure. Whey can be used as a substitute for water as a means to reach optimal solids percentage of the manure slurry. One whey-based system has been installed in New York at Marks Dairy Farm, which utilizes roughly 12 million gallons of whey each year, in combination with manure from their 5,000 cows, to produce 2-3 MW electricity per hour. The large amount of whey used in this system is supplied by the nearby cheese producers Kraft and Lewis County Cheese (Alban, 2003). Scott and Ma (2006) report on the energy production of existing AD systems in New York State. They find that the combined food waste-manure system at Matlink Farm (which has 740 cows) produces over four times the biogas per cow (326 ft^3/cow/day) than does a manure-specific system at AA Dairy (500 cows, 85 ft^3/cow/day). While these are not small dairy operations, the numbers are suggestive of the superior energy return potential via utilizing other waste resources in conjunction with manure. Food wastes come in many forms, some of which may carry a high tipping fee or transport cost. However, if a small dairy or its neighbor were to be a cheese-processor, whey could be a readily available and cheap digester additive that would increase the electricity production potential of the system.

Our consultation with a local dairy farmer indicates a potential willingness to further investigate AD implementation on his own farm in the future. Information and funding were identified as primary barriers, but the interest in energy self-sufficiency is there.

Previous studies and our interviews, thus, indicate significant barriers as well as great potential for the near-term viability of anaerobic digestion on farms with fewer than 100 cows. Both independent and cooperative systems could be implemented at a net positive energetic and financial return on this scale given a few developments in the renewable energy market and the AD industry (Bennett).

d. Recommendations

Our work provides a foundation for the unification of knowledge, case studies, and technological innovation to support the establishment of small-scale anaerobic digestion systems in Vermont. Through a basic consultation framework, such as our Methane Digestion Feasibility and Willingness Assessment (Appendix D), coupled with forthcoming growth in the AD industry, which will lead to potential economies of scale and technological innovation as well as technical familiarity, the viability of building a small farm AD industry in Vermont will grow. Continued work to bring together the stakeholders in agriculture, electricity, technology, business, and government will be crucial to the success of AD development. The parties that will need to be involved to ensure AD success in Vermont will include dairy farmers, state legislators & energy companies (to develop financing opportunities and rate schemes that provide incentives for AD operation), system engineers, builders, operators, and servicers. We recommend that interested organizations work to unify the goals and interests of these stakeholders, while also practically increasing the AD industry through funding, research and development, and enabling policies. This may take the form of a national organization dedicated to bringing together the resources necessary to advance digester technology and leverage the political capital needed to attract the necessary funding resources.

In Germany, there is a privately owned national biogas association called The German Biogas Association (www.biogas.org), which may provide a useful model for the United States to build its own such organization. Similarly, the United States wind industry is organized through the American Wind Energy Association (www.awea.org). We encourage the domestic private sector to create an anaerobic digester organization to serve as a clearinghouse for AD information for US farms. This may be accomplished through the coordination of efforts by the Federal and State Departments of Agriculture (http://www.usda.gov/energy/), the EPA's AgStar program (http://www.epa.gov/agstar/), and various smaller projects such as AgRefresh (http://www.agrefresh.org/) and the Vermont Agency of Agriculture's Vermont Methane Pilot Project (http://www.vermontagriculture.com/). Each of these agencies and organizations is leading the way towards wider AD development. The future of small scale AD

implementation would greatly benefit from their coordinated concentration on the development of small scale systems and the necessary economic conditions for viability.

In addition to a cooperative process to increase AD feasibility, the potential for an integrated business system to develop, operate, and service ADs should be investigated. It is possible that the state or a private firm could best develop the AD industry, as opposed to disconnected single operations. Such a system might take the form of mass implementation of state or firm-contracted AD systems on private farms through the development of "off-the-shelf" system designs applicable in many farm situations and scalable to specific farm sizes. Under such a model, the individual farms would host the digester, provide the digester feedstocks (manure and crop waste, etc.), and daily operation and labor, but the systems would be constructed and maintained by the state agency or digester firm. This type of system would address the capital cost inhibitor by allowing for mass contracting, design, and construction of digesters to generate economies of scale. Furthermore, a state agency or digester contracting company could reduce operation and technical requirements and risks placed on farmers, through creating a market for AD technicians who would service and maintain the individual systems as employees of the state agency or the digester firm. Such an arrangement would potentially reduce the monetary costs and the operational and technical hassles currently associated with a digester undertaking, making small farm implementation of AD systems more viable. GHD Inc., of Chilton, Wisconsin, is an example of a private firm that provides the whole range of AD process services, including design, installation, permitting, start-up, and maintenance (www.ghdinc.net). GHD Inc.'s systems, however, are currently still designed on a site-specific basis for farms of 600-3,600 cows. More applicable as a model firm is Avatar Energy, of South Burlington, Vermont (www.avatarenergy.com). Avatar has worked to develop a mass-producible, modular, scalable AD system for farms with 40-200 cows that creates energy through a combined heat and power system. Like GHD, Avatar's services include site development, installation, service, and financing assistance. Thus, Avatar provides a useful business model, which we recommend that the state either support or duplicate to enhance the implementation of small AD systems in Vermont.

We also recommend that policy be put into to place that would require the reduction of greenhouse gas (GHG) emissions. Much of the rest of the world has already taken this step by signing the Kyoto Protocol. If the United States created laws and regulations to limit greenhouse gas emissions, a financial incentive for renewable energy development would be created. The installation of ADs would be one way to meet GHG reduction regulations while also providing economic benefits. In the current absence of domestic GHG reduction mandates, renewable energy credits provide an established, politically feasible means to incentivize ADs. Channeling efforts into the development of an efficient and high quality market for RECs would help raise the economic viability potential for small AD system operation.

Given the status of and potential avenues for successful anaerobic digestion in Vermont, our main recommendation for our community partner is stimulate and direct stakeholder energy towards the suggested coordination of state or national efforts. Futhermore, it appears imperative to Vermont's AD potential that small, scalable and modular systems capable of utilizing both manure and crop or other organic wastes are rapidly developed. Our community partner should work towards the focusing of AD efforts by engineers on the development of such systems. Additionally, our community partner should seek to identify small farm clusters in Vermont where manure, crop waste, food processing waste and/or wood waste are available in close proximity to one another. Such locations would be prime candidates for a willingness and farm practices feasibility assessment to determine the viability of a cooperative combined-waste digester system.

Garrett, *et al.* (1999) define a "community food system" as one "in which sustainable food production, processing, distribution and consumption are integrated to enhance the environmental, economic, and social and nutritional health of a particular place." Anaerobic digestion is one way to move towards a "community energy system" ideal. ADs integrate energy consumption and production, which enhances the environmental, economic and social health of Vermont via its small dairy farms.

The first two components of our farm-energy project—geothermal heating/cooling and anaerobic digestion—have explored ways to reduce energy needs and produce renewable electricity on the farm. Farmers, however, also have a high demand for liquid fuels for the purposes of heating, transportation, and the operation of equipment and

machinery. The next section of our report will explore how local biofuel production can satisfy these needs.

IV. Biodiesel Production and Use on Farms: Localizing Vermont's Fuelshed

a. Introduction: A Background on Biofuels

In recent years, biofuels have entered the mainstream of discourse on energy, especially in the transportation sector. Biofuels are plant-based fuels that can be used in internal combustion or compression engines, the most popular of which are ethanol, a distilled grain alcohol, and plant-oil based biodiesel. They are biodegradable, non-toxic, and carbon neutral, and can be produced from various plants in nearly every country in the world. Though there has been a recent resurgence in biofuels, many of the first automobiles ever built ran on plant derived fuel, including Rudolph Diesel's first peanut oil fueled compression engine. Concerns about energy security, environmental degradation, and climate change have encouraged many analysts, policymakers and academics to look for alternatives to unsustainable fossil fuels. More than 80% of the world's primary energy consumption comes from fossil fuels, and as figure 8 shows, about 50% of the petroleum is consumed by the transportation sector. The sheer numbers are cause for concern. Biofuels, which can be produced using little energy inputs and from many different crops, present a compelling alternative energy opportunity.

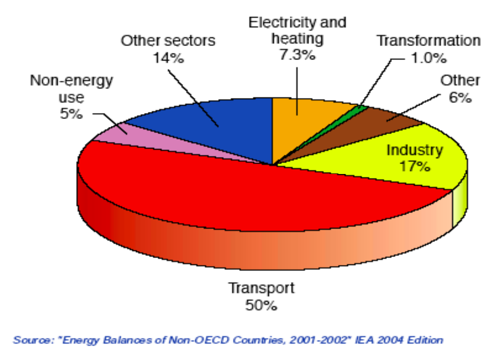

Figure 8: A graphic representation of world petroleum consumption.

Aside from the environmental and climactic benefits of producing biofuel, the potential for it to revitalize local economies in rural areas shows great promise. Farmers all over the world and in the United States can, at relatively low cost, produce fuel that can be consumed locally, reinvesting a significant amount of money that would have otherwise left the community. Though the data are still emerging, early research examining the economic viability concludes that oil seed crops, when grown at

appropriate scales, can be developed into biofuels at prices competitive for the consumer and profitable for the farmer. Biofuel production has the potential to make a struggling sector of the economy—agriculture—into a significant and robust part of the global liquid fuel market. To bring this back to the local level, this report will assess the potential for biofuel production in Addison County, focusing primarily on how to engage farmers in the preliminary steps of the process.

b. Biodiesel Basics

Biodiesel, in chemical terminology, is known generically as *alkyl ester*, and is produced through a *transesterification* process. Vegetable oil molecules are considered triglycerides, referring to the three fatty acids connected to glycerin, which makes the oil thick and sticky. Since glycerin makes the vegetable oil too viscous to be used as a fuel, the biodiesel production process mixes ethanol or methanol with the vegetable oil, thereby breaking the chemical bond between the glycerin and the fatty acid chain. The resulting molecules contain fatty acid chains connected to one of the alcohols, forming either *methyl ester* or *ethyl ester*. To make the transesterification reaction occur in a timely fashion, one must also add a catalyst and heat. Sodium hydroxide, more commonly known as lye, is the most popular catalyst in both small-scale and industrial size biodiesel plants, though other caustic sodas can also be used. The three basic ingredients—vegetable oil, methanol/ethanol, and lye—can be processed at nearly any scale using a batch process, in which all of the ingredients are mixed together in a container, and within a few hours biodiesel has separated from glycerin and catalyst. Using cone-shaped tanks, the glycerin can be siphoned from the bottom, leaving biodiesel on top.

Various commercial producers and 'homebrewers' in Europe, Australia, and the United States use other processes, such as biodiesel washing and filtering to bring the fuel up to government standards, but this is not necessary for use in most engines. Biodiesel production plants range from a 55-gallon drum in somebody's backyard or shed to plants in grain-growing regions of the United States and Europe that produce upwards of 500,000-1 million gallons of biodiesel per year. As biofuels become more popular, the technology of production will most surely become more complex, though the chemical

process will remain the same. In the United States and Europe, there are already engineering groups who sell large-scale plants that need only a few full-time employees and require little more than the turn of a key to begin producing. The feedstocks as well as the scale of the facility have been shown to have a significant bearing on the cost of producing biodiesel, which varies between roughly $1.00/gallon using waste vegetable oil and $3.25/gallon using rapeseed/canola (Worldwatch/GTZ, 2006:10). With petroleum diesel prices at around $3.00/gallon at the pump in much of the United States, and more expensive in Europe, it is understandable that the biodiesel industry is subject to fluctuations in the price of oil. The economic margins of production are so small, in many cases, that when the price of oil is down, demand for biodiesel goes down, and when the price of oil is up, demand increases significantly. This is due in no small part to the fact that the biodiesel industry, in its feedstock cultivation, production processes, and transportation, depends heavily on fossil fuels. Despite the fact that biodiesel is generally about the same price or more expensive than diesel fuel at the pump, world production increased tenfold from 1996 to 2006, from about 500 million liters to nearly 5 billion liters per year (Worldwatch/GTZ, 2006:5).

Much of the interest in biodiesel stems from the fact that it *can* be produced more cheaply and efficiently if certain feedstocks were used that yield more oil, the basic ingredient. Currently, the vast majority of biodiesel in the world—about 85%—is produced from rapeseed/canola oil, which can be cultivated in northern climates. Rapeseed yields about 1000 liters of oil per hectare, while sunflowers and soybeans, the next most common biodiesel feedstocks yield roughly 700 liter and 500 liters respectively (Pahl, 2005:48-50). This hits on a larger concept that must be investigated thoroughly in discussing biofuels: Energy return on energy invested (EROEI), which is also known colloquially as *energy balance*.

If the object of biofuel production worldwide is to decrease dependence on fossil fuels, reduce greenhouse gas emissions, and provide low-cost energy, then the energy inputs of the process with respect to fossil fuel consumption must be less than the biodiesel output. Some studies have shown that biofuels have negative energy balances when all of the energy "costs" such as electricity use, production process and transportation are added in, most notably with corn-based ethanol (Patzek & Pimentel,

2005:359). Despite some controversy, biodiesel from waste vegetable oil or virgin rapeseed, sunflower, and soybean oil is generally agreed to yield between 2.5 and 6 times the energy input (Institute for Local Self Reliance, 1994:3; Worldwatch/GTZ, 2006:17).

c. Biofuels in Vermont – Localizing Vermont's Fuelshed

The potential for homegrown fuel in Vermont is exciting from the perspective of the state's economic health, energy security, environmental sustainability, and the long-term viability of the state's dairy farms. At this time more than $400 million leaves the state annually to pay for crude oil and refined diesel products, including more than 60 million gallons of diesel fuel for transportation (Vermont Biodiesel Project, 2006: 4). This staggeringly large sum is tied to a complex, international system that is anything but sustainable. With this in mind, we focused our research on finding ways to keep more of this money in-state—how to localize our "fuelshed" so that it looks more like a "watershed." With many analysts predicting a continued rise in fuel prices in the coming years, the economic incentive to produce oilseed crops is likely to increase. Localizing our fuelshed through a homegrown fuel industry could create new jobs for Vermonters and nurture local economies. It could also help liberate the state from volatile pricing mechanisms dependent upon the actions of unstable nations. The environmental advantages of biofuel are numerous: lower emissions (particulates, sulfates, and carbon monoxide), reduced impact from transporting fuel, and lower greenhouse gas emissions. Finally, biofuel provides a promising alternative future for Vermont's agricultural landscape, increasing the economic viability for struggling farms across the state.

d. A Framework For Assessing Vermont's Biofuel Potential

It should be noted that due to our constraints on time and research, our personal areas of expertise, and the specific requests of our community partner at the Vermont Biofuels Association, our work focused on the production of biodiesel, one prominent kind biofuel that seems especially well-suited for development in Vermont.

To grow biofuel crops in Vermont, many elements must come together. What follows is a framework of how these elements can be synthesized into a comprehensive

program designed to facilitate the development of a viable biofuels industry in Vermont. There are several elements crucial for the development of this program that we do not explore here, including agronomic research, economic feasibility research, building market demand, allocation of state funding, and the development of supportive policies. Many of the aforementioned elements are being researched and developed by a consortium of organizations, including the Vermont Biofuels Association, the Vermont Sustainable Jobs Fund, the UVM Agricultural Extension, and more. With these concurrent initiatives in mind, we focused on two areas not being explored by other organizations: GIS analysis and attitudinal/resource assessment of local farmers. Our work in these two areas led to a new understanding of potential work to be done in two other areas: farmer education and outreach, and the development of a biofuel farmer network and mentorship program. When combined, these four areas of work represent crucial elements of a larger program for developing the resources, knowledge, and infrastructure necessary for a local biofuels industry.

We will first outline each of the four aforementioned areas, their importance, and a summary of the relevant work that has already been done in each area. We will then describe the specific methodologies and results of our GIS analysis and our attitudinal/resource assessment.

1) GIS Analysis:

What:

- Geographic Information Systems (GIS) can combine many types of data into a visually accessible and informative map.

Why:

- This multi-layered map can help to identify how much land in a given area is suitable for the production of biofuel crops.
- GIS analysis can also reveal the specific areas that have the potential for highest yields, farms that are well-positioned for easy transportation of oil seeds, and clusters of farms that could collaborate on processing and transportation of biofuel crops.

Existing Resources:

- To our knowledge, there has been no GIS work to date that specifically analyzes the potential for biofuel production on Vermont's lands.

2) Attitudinal and Resource Assessment of Local Farmers

What:

- A thorough assessment of current attitudes, knowledge, and resources among local farmers.
- Target two categories of farms: those already growing oil seed crops for biofuel, and those growing oil seed crops for other purposes.
- Questionnaires and interviews should be used as appropriate.
- Additionally, a focus group that gets several farmers together in one place could be very informative.

Why:

- Surveying area farmers would help to build the collective knowledge of a given area. Qualitative information from interviews and surveys can help determine which seed varieties, methods, and resources have proven most effective for the production of biofuels.
- An attitudinal assessment can also identify barriers to progress and areas of need: from subsidies to general education, collaboration to technical specifications.

Existing Resources

- The Vermont Biofuels Project conducted a set of surveys in 2005-2006 to assess general interest in biodiesel. These surveys indicated a high level of knowledge and interest in biodiesel. (*Building Demand in the Biofuels Sector,* pg. 19). However, these surveys were not targeted at farmers, nor did they deal with issues of fuel production. To date, assessments of Vermont farmers' attitudes and resources related to producing biofuels have been informal, anecdotal, and undocumented.

3) Educational and Outreach for Farmers

What:

- A comprehensive biofuels education program that is specifically designed for farmers. This program could include:
  - Open general information sessions for farmers on growing oil seed crops. These sessions could provide an important educational opportunity for those unfamiliar with biofuels.
  - Outreach pamphlet to be distributed to local farmers. This pamphlet can describe basic information about biofuels, while leaving out some of the more technical details.
  - A "How-To" packet/booklet that covers the nuts-and-bolts of producing biofuel, from choosing a crop to pressing the seeds to navigating state regulations.

Why:

- Fully understanding the options, opportunities, and risks can help local farmers make an informed decision regarding growing biofuel crops.
- Many farmers are open to diversification and the biofuels market is perceived as a new, growing, exciting option for farmers. However, if these farmers do not have easy access to information on biofuels, or if that information is not presented clearly and concisely, farmer interest will not translate into widespread action.

Existing Resources

- There has been considerable educational outreach for biofuels in Vermont, though little of it is targeted directly at farmers. Much information is available on the internet (http://www.vermontbiofuels.org/, http://www.vtbiodieselproject.org/partners/partners.shtml) though some farmers do not have the time, means, or inclination to browse the web.

4) **Biofuel Farmer Network & Mentorship Program**

What

- This program could connect farmers with some experience growing and processing oilseed crops to those farmers just getting started.

Why

- Biofuel producers are rare in Vermont, and farmers involved in this emerging industry often feel like pioneers with no one to turn to for advice or assistance. Sometimes, information from a pamphlet, the internet, or a non-profit organization is not enough. In these cases, personal connections between farmers can be invaluable.
- With more new farmers every year becoming interested in growing biofuel crops, a defined mentorship program can help to transfer bioregionally specific knowledge and skills.
- Once these farmers have been connected through the Biofuel Farmer Network, they can mobilize more easily to advocate for supportive policies, as well as lay the foundation for a potential cooperative network to process and distribute biofuels.

Existing Resources

- To our knowledge, relationships between local farmers producing biofuel crops are informal or non-existent, and no effective network currently exists for connecting them to each other.

e. GIS Analysis

For this analysis, we used the USGS/Anderson land use/land cover classification scheme to determine which areas of Addison County are currently planted in row crops and hay/pasture. This classification, while helpful, is only about 80% accurate in determining true land use (USGS, 2006). Our work should be followed up with ground-truthing and in-depth interviews with farmers regarding their crops. The following data show that there are a total of 186,041 acres of land currently in row crops and hay/pasture, roughly equally divided among the two categories (see Figure 9). A spatial representation of these data can be found in Figure 10.

TOWN NAME	**Area (acres) Hay/Pasture**	**Area (acres) Row Crops**	**Total Ag Area (acres)**
ADDISON	8795	11121	19917
BRIDPORT	11089	10252	21341
BRISTOL	1794	2925	4718
CORNWALL	5453	4916	10369
FERRISBURG	9643	10114	19757
GOSHEN	20	612	632
GRANVILLE	107	800	907
HANCOCK	61	509	571
LEICESTER	1158	2385	3543
LINCOLN	529	1755	2284
MIDDLEBURY	4962	5002	9964
MONKTON	3392	4195	7586
NEW HAVEN	7544	8468	16013
ORWELL	8678	7220	15898
PANTON	3556	4059	7615
RIPTON	55	767	822
SALISBURY	3046	2333	5380
SHOREHAM	10405	8920	19326
STARKSBORO	1251	2178	3429
VERGENNES	436	558	995
WALTHAM	1626	1906	3532
WEYBRIDGE	2803	3906	6710
WHITING	2656	2053	4708
Total Addison County	**89061**	**96953**	**186014**

Figure 9. Addison County Agricultural Land Use

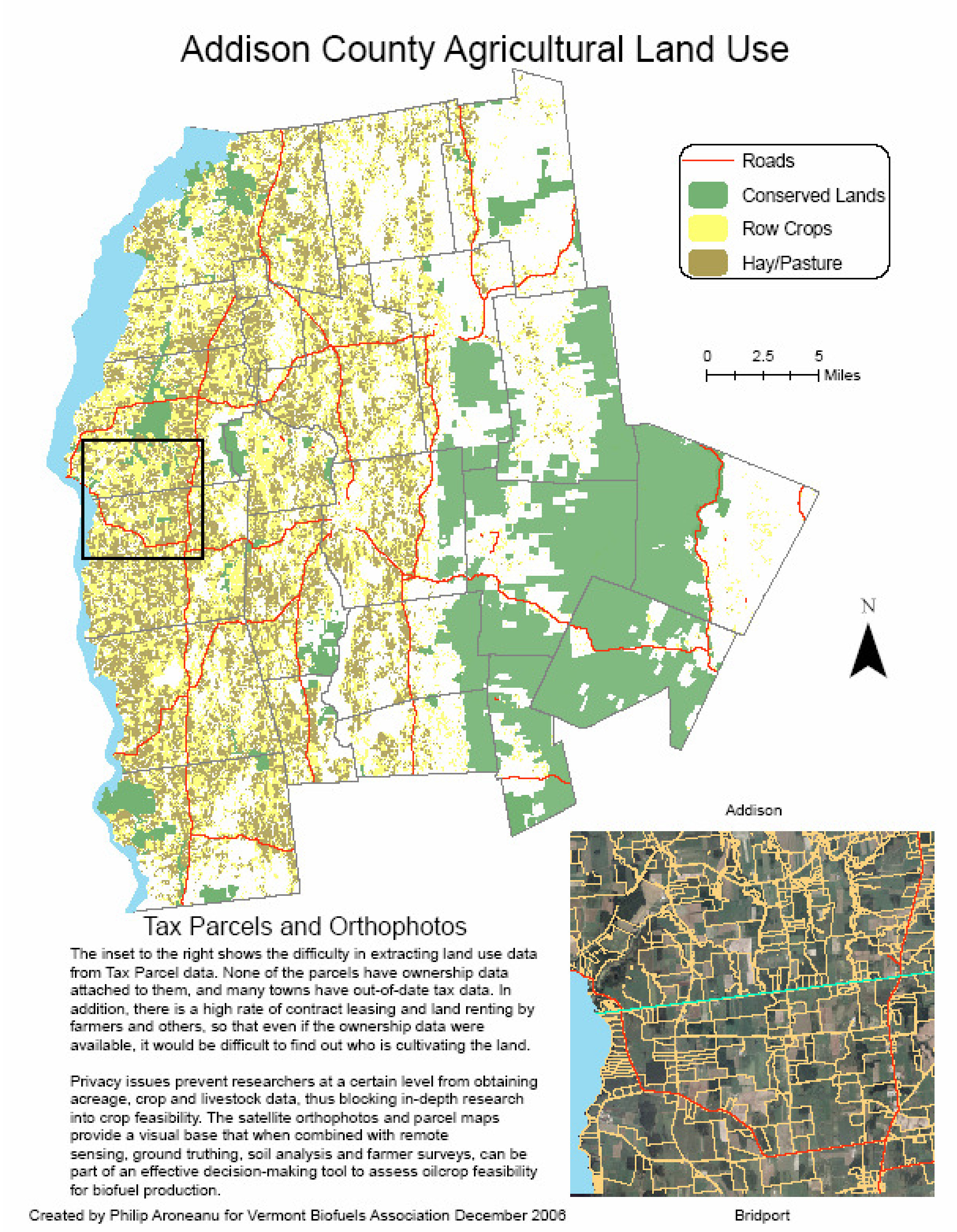

Figure 10. Map of Addison County Land Use

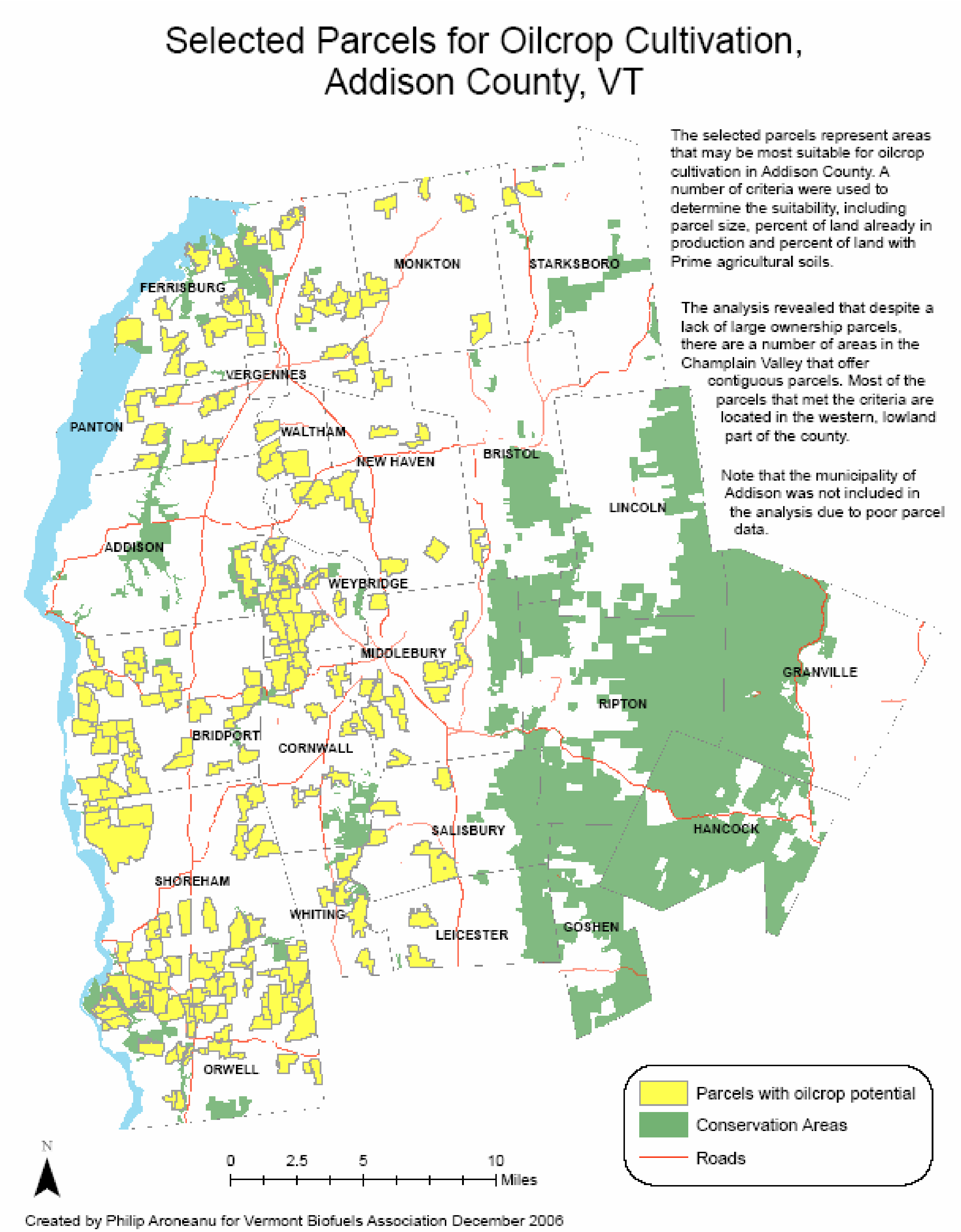

Figure 11. Selected Parcels for Oilcrop Cultivation, Addison County

The map in Figure 11 builds on the agricultural land use data used in Figure 10. In an interview, John Derrick, a farmer who has been involved with the Vermont Biofuels Association and the Middlebury College Organic Garden, mentioned that the minimum amount of land required to grow soybeans economically is about 1000 acres. Because the Vermont Biofuels Association has expressed interest in working with landowners and farmers who have significant acreage at their disposal, we chose to limit our analysis to parcels over 200 acres. For each of these 200+ acre parcels, we considered the percentage of land currently in hay/pasture or row crops in each parcel. Those with less than 50% currently in cultivation were then excluded. The final criterion we used to determine parcels that would be effective for oilcrop cultivation was the percentage of prime agricultural soil in each parcel. "Prime" is a term defined by the United States Department of Agriculture as "Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is also available for these uses" (USDA, 2000:724). We chose parcels that had at least 50% prime agricultural land, according to the USDA definition. The total resulting areas available for oilcrop cultivation in selected parcels, according to the criteria we set, amounted to 55,947 acres.

The map in Figure 12 was made using the same selected parcel data from Figure 11. The orthophoto base map enables the Vermont Biofuels Association to pick out individual parcels and areas where cooperative cultivation may be possible. Because of the lack of individual parcel information at this level of analysis, it is often difficult to know exactly where property lines may be, and which fields may be leased out. Seeing satellite photography of a region, however, can help the viewer appreciate the landscape more fully. We enlarged the Champlain Valley area of Addison County to highlight three major clusters of selected parcels. As the costs of new equipment for cultivation, harvesting and biodiesel production are high, cooperative efforts may benefit farmers by reducing their capital investments. Three main areas with contiguous or nearby areas of large parcels include along the Weybridge/Cornwall town line, the Bridport/Shoreham town line, and much of the town of Orwell.

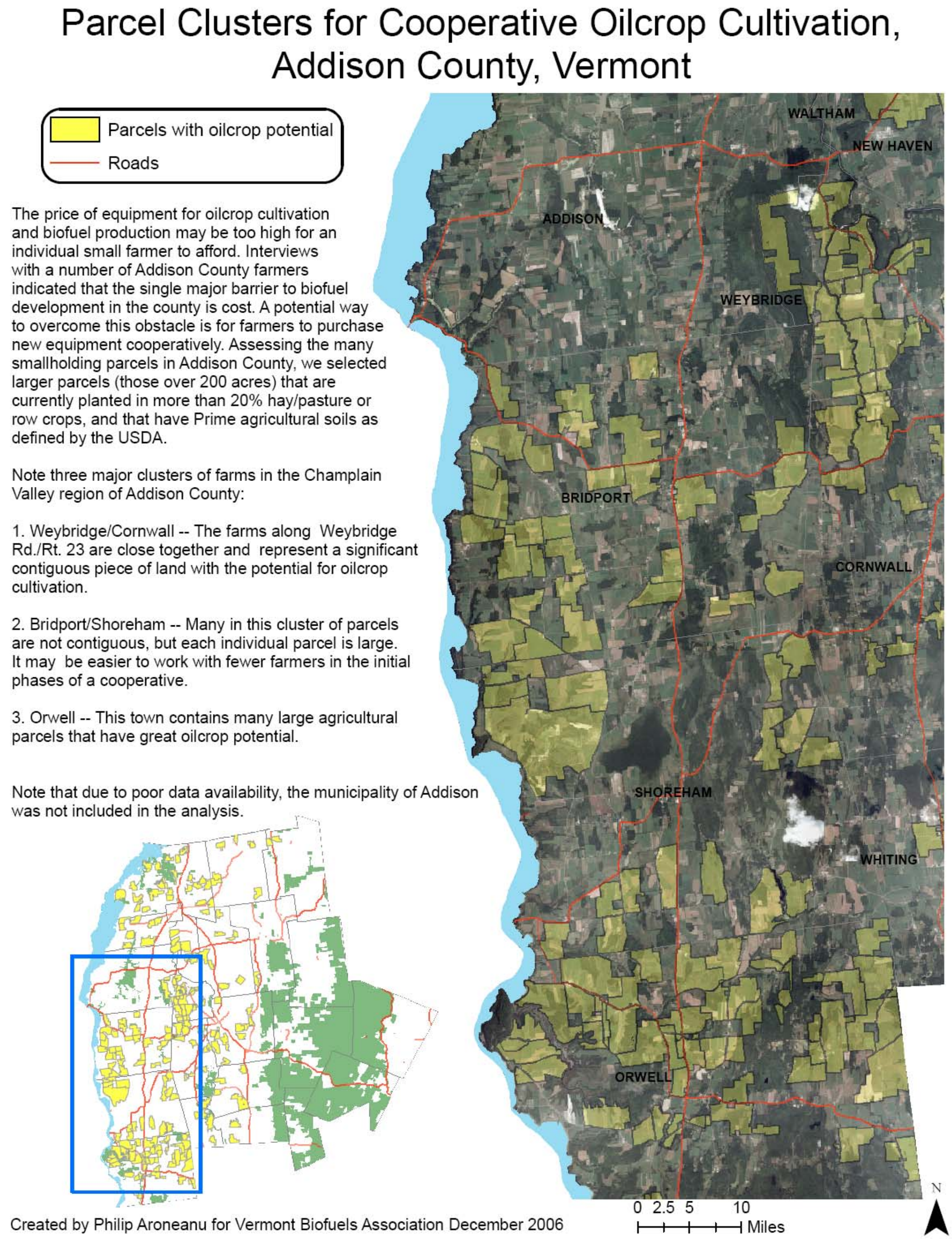

Figure 12. VT Parcel Clusters for Cooperative Oilcrop Cultivation, Addison County, VT

f. Attitudinal and Resource Assessment of Local Farmers

To assess the current attitudes of local farmers and the availability of resources critical to growing biofuel crops, we identified potential farmers who would be ideal candidates for our line of inquiry. There were many factors that went into this, including: farmer experience, current farming operations, size of farm, viability of current farm setup, and more. Once we had identified our potential farmers, we considered different methods to connect with those farmers to get their feedback. An internet survey had previously failed to attract responses from this community of farmers and we felt a written survey might face the same challenges. We concluded that informal interviews with the farmers, either over the phone or face-to-face, would produce a more accurate and useful assessment of local farmers than a written or internet-based survey.

We developed a short set of questions that would facilitate an informative and efficient (farmers don't have much free time!) conversation to assess the current barriers and opportunities to developing a viable biofuels industry in Vermont. Working in collaboration with Netaka White of the Vermont Biofuels Association, we narrowed our questions to the following:

1. Do you raise livestock? In what capacity?

2. Have you ever grown soybeans, canola or other oilseed crops? If no, skip to #3, If yes:

   - How many acres did you plant in 2006? In 2005? On average over the last x# of years?
   - What varieties, and what have your yields been?
   - How is your soybean or other oilseed crop being used?
   - If you aren't using it for your own livestock, where do you sell it?
   - Could you potentially grow more? How much more?
   - (skip to #6)

3. What, if anything, have you heard about growing oilseed crops?

4. Have you ever considered growing such crops yourself?

   - If no, what are the barriers that are preventing you from considering it as an option?

5. If you were to grow these crops, approximately how much cropland could you commit, in rotation, to the production of oilseed crops?

6. Do you already have any (or all) of the necessary equipment for small grain planting, cultivation and harvesting?

7. Right now, varieties of soybean and canola that are not genetically modified are difficult to obtain. Is growing GMOs an issue for you?

8. How much diesel and heating oil do you use each year?

9. Would you be more willing to grow oilseed crops if you knew you could share equipment, knowledge, and resources with nearby farmers to aid with the processing of seeds to biodiesel?

10. Do you think there is a role for agriculture to produce energy in Vermont?

These questions served as a rough guide for our interviews, though our conversations often extended far beyond the scope of these questions. These conversations (with five farmers in total) are not transcribed here. In place of such lengthy transcriptions, we have condensed and distilled our general impressions, focusing on the principle themes that came up with several farmers. Additionally, a few quotes that we found especially pertinent have been included, with farmers' names removed for the purposes of anonymity.

General Impressions and Themes

- **Lack of Information:** Farmers repeatedly emphasized the need for hard numbers (i.e. economic analysis) and nuts & bolts information (i.e. technical and resource requirements) in a complete, accessible package.
- **Lack of Confidence:** Farmers identified a growing feeling across the state that diversification is necessary to improve long-term viability of farms, but are uncertain about biofuel crops.
- **Lack of Support:** Several farmers identified the need for a farmer-to-farmer network, akin to the "Grain Growers Association" but specializing in biofuel crops. Such a network would allow farmers to share knowledge, resources, and perhaps mobilize more policy support for biofuel crop development.

Direct Quotes

- “We need a few people to take some risks to make this happen…that’s why it would be great if the college explored biofuels.”
- “What farmers need most right now are hard figures—the real numbers that show them: yes, you can do this stuff and make a buck too.”
- “Above all else, we need to get people to understand that we NEED to change our way of life…that adjustment in attitude will be the greatest thing we can do to not only build the biofuels market, but to get more farmers on board.”
- “My neighbors are other farmers, and most of them are interested in biofuels, but they need a little prodding to take the plunge. Not only are they set in their ways, but they are very busy with the operation they have. But, if they could see examples of this thing working all around them, if they could watch the press make oil and watch that oil power their tractor…well, it wouldn’t take much convincing after that.”
- “What’s missing are the messengers. It’s great to do some test plots, post the results on the web, and show that it can be done. But really, you need real people going out to farmers, saying ‘Hey, this works, here’s how to get started.’ This is where I think students and young people come in. You have the most stake in all of this. We need you to take this message to farmers, and speak it loudly, face-to-face, person-to-person. ”

g. Recommendations

Though much work remains to be done to make biofuels a viable industry in Vermont, many of the pieces are starting to come together. Our research—based on GIS and attitudinal assessments—has given us reason to believe that we already have the land resources and general interest in place. Our GIS analysis and attitudinal assessments pointed towards the further development of two specific initiatives. Our two primary recommendations call for the development of 1) a comprehensive biofuels education and outreach package, tailored to Vermont farmers interested in cultivating biofuel crops, and 2) a farmer-to-farmer biofuel crop growers network. These two programs, coupled with

the continuation of existing research and initiatives of the Vermont Biofuels Association, could take advantage of Vermont's massive potential to unroll a profitable biofuels industry in the coming years. This process must be built upon focused education, rigorous economic and agricultural research, and intensive collaboration at all levels.

V. Farm Energy Project Conclusion

Our Environmental Studies Senior Seminar introduced diverse concepts related to the topic of "Healthy Local Communities," and ultimately demanded a reassessment of what such a community would look like in practical terms. We reached the broad conclusion that this new vision of community requires two basic elements: a respectful interdependence among the various elements of a given community, and self-reliance of the community within increasingly unsustainable global systems. It is evident that the small farm, as a nutritional and economic hub, is a vital component of any healthy local community.

Given the centrality of farms to this new vision of healthy local communities, it is especially important to preserve Vermont's agricultural tradition. Many of Vermont's small farms are currently struggling to survive in the increasingly competitive global marketplace. Contributing to this struggle are the rising costs of energy for electricity, heat, and transportation. This trend reduces a farm's profit margin and thus threatens its long-term financial viability. As such, Vermont is poised to take a leadership role in the development of energy-efficiency programs and renewable energy industries based on its small farms. Such systems would not only create opportunities for energy self-sufficiency, but would allow farms to generate further revenues and offset costs.

There are a wide array of new energy options that Vermont's small farmers can explore; our project assessed three of these avenues of potential development. Geothermal technology offers an exciting an opportunity for significant efficiency gains on Vermont's dairy farms, but is in desperate need of more research and increased funding. Anaerobic digestion offers the prospect of reducing electricity costs and creating new sources of potential income, but requires increased state and national-level coordination, as well as the rapid development of scalable digestion technology. Finally, the potential to create a homegrown biofuels industry will never be realized without significant educational efforts, increased support networks, and the implementation of supportive policies.

We have learned technology alone is not enough: these solutions can only be effective if attitudinal, structural, and financial barriers are removed. Any restructuring of on-farm energy use and production demands a major educational effort, an effort that

must be focused, strategic, and sustained. Furthermore, policies and subsidies that facilitate and incentivize efficiency and on-farm energy must be aggressively pursued.

Ultimately, there are no easy answers to the energy challenges facing Vermont's farmers. Perhaps our greatest lesson is that the silver-bullet does not exist—there is no single solution that will apply to all farms. A synthesis of different solutions is needed, with customized energy programs for individual farms. Some farms should firstly focus on their efficiency before undertaking on-farm energy production. Looking at the larger picture of Healthy Local Communities, off-farm energy production should be addressed as well to encourage a re-distribution of the Addison County "fuelshed."

Though much work remains to be done, our overall assessment leaves us optimistic about the many opportunities available for energy production and energy efficiency on Vermont's farms. Through a combination of good design, new technology, focused education, strong incentives, strategic collaboration, and common sense, new models of agricultural energy use will continue to emerge. With these new models, Vermont's farms can remain vital economic and nutritional hubs of the community, embodying the self-reliance and interdependence a healthy, local future so desperately requires.

Appendix A:

GEOTHERMAL HEAT PUMP VENDORS IN THE NORTHEAST

This list was adapted from the list of vendors participating* in Public Service of New Hampshire's ENERGY STAR® Homes Program as of May 2005.
* Participation means having installed a system in the program within the past two years.

Water & Energy Systems
4 Wilder Drive, Suite 14
Plaistow, NH 03865
Contact: Carl Orio
Phone Number: (603) 378-9122
Fax Number: (603) 378-2085
Web: www.northeastgeo.com
Email: carlo@northeastgeo.com
Heat Pump Mfg: ClimateMaster
www.climatemaster.com

Garth Gibson
444 County Route 32
Valatie, NY 12184
Phone Number: (800) 934-5160 x8869
Email: garth_gibson@waterfurnace.com

Heat Pump Mfg: WaterFurnace
www.waterfurnace.com

Efficiency Plus Corporation
PO Box 407
Tiverton, RI 02878
Contact: Mel Hensch
Phone Number: (603) 303-8476 or (508) 328-4735
E-mail: Efficiencyplus@cox.net

Heat Pump Mfg: ECR Technologies, Inc.
www.ecrtech.com

New England Ground Source
David Cardill
www.negeothermal.com

Appendix B: Energy Bill for a Small Dairy Farm

The following information offers one example of energy use on a small dairy farm in Vermont. This farm has about 50 cows and 200 acres. The energy bill can reveal areas of inefficiency and help determine the feasibility and costs of new energy systems. While we did not receive the data early enough to do calculations or make suggestions, we hope the information will be useful to our community partners and those interested in energy issues on small farms.

Propane

Oct-Dec 246 gal

Jan-Mar 202 gal

April-June 130 gal

July-Sept 129 gal

Electric

Oct-Dec $1179

Jan-Mar $1315

April-June $1174

July-Sept $1519

Kerosene (to cut diesel in winter)

Nov-Dec 116 gal

Jan-March 90 gal

Diesel

Oct-Dec 235 gal

Jan-Mar 210 gal

April-June 310gal

July-Sept 420 gal

Appendix C:

MARKET AND ECONOMIC ASSESSMENT FRAMEWORK

MARKET QUESTIONS (byproducts)

- What are current farm expenses on:
    - Fertilizer?
    - Compost?
    - Bedding?
    - Water treatment?
    - Water heating?
    - Ambient heating?

MARKET QUESTIONS (energy)

- What is the current on-farm demand for electricity in Vermont?
    - Equipment?
        - Milking
        - Cooling
        - Barn
    - Heating?
    - Other?
- What is the current and projected price being paid for electricity? Annual electricity bill?
- What is seasonal cycle of energy demand? Daily cycle? What is absolute peak demand level?
- Other?

EXPENSES and INFRASTRUCTURE DEVELOPMENT

- What is the total capital cost of a given AD system configuration?
    - Digester
    - Boiler
    - Liquids/solids storage and separation
    - Generator
    - Pumps, plumbing and electrical
    - Engineering/planning & design
- What are the operation and maintenance costs?
    - Operation inputs (any energy to run the digester, cellulosic or other mix-ins)
    - Maintenance and repairs
    - Daily labor (or opportunity cost of farmer's time spent on digester work)

INCOME and YIELDS

- What is the current range of energy yields for the different systems? How much does it vary throughout the day? Seasonally? How much does energy output depend on amenable ambient temperature?
- Calculate the range of potential gross and net income for each product stream.
    - Energy – replacement, net metering sales, carbon/green energy credits

- Solid - compost or bedding
- Liquid – fertilizer replacement
- Ambient heating replacement
- Other – valuation of potential for less environmental risk, permitting violations or odor-related suits?
- Other?

OTHER

- Cooperative potential: where are there small (100 or less cows) dairies within, say, 2-5 miles of each other that may have potential to establish a cooperative AD?
- Calculate the range of "net deliverable Btu" for the manure to electricity process using this model.
  - In order to answer the question "*What is the EROI* (Energy Return on Investment)?"
- List production barriers
  - Dairy size (often smaller than what is generally seen as economical for AD operation)
  - Capital costs, coupled with lack of funding
  - Lack of technical expertise – especially among farmers, but also in the still developing industry of digester technology and engineering
  - Current failure rate of AD projects
  - Lack of farmer time to deal with daily digester needs
- List market barriers
  - Cheap energy availability
  - Need easier access to markets/ business expansion into compost or bedding sales, RECs
  - Need valuation system for environmental co-benefits
- List opportunities for statewide collaboration
  - VBA
  - NOFA
  - 25x25
  - CVPS
  - AgRefresh
- List needed regulatory and policy enhancements (or changes)
  - Financing: Grant opportunities, tax incentives, rebates, low interest loans
  - Decrease in permitting burden
  - Increase in ease of connecting to net metering systems

Appendix D:

METHANE DIGESTION FEASIBILITY AND WILLINGNESS ANALYSIS

I. Energy and Efficiency Basics
- What is current annual energy bill? How does this translate into per cow energy usage?
- What are the major energy consuming operations/technologies on the farm?
- What energy efficiency measures are in place? What can easily (cost effectively, and without high capital costs) be implemented to reduce energy demand on farm?
- How does overall energy demand vary seasonally? Where does the change take place? (i.e. Switch off fans and switch on heaters).

II. Manure Load Assessment
- How many cows are on the farm?
- What is current annual manure output that is captured?
- How much does manure capture vary seasonally (i.e. How much of manure may be lost during pasture time in the warmer months)?

III. Manure Handling Assessment
- How is manure currently collected?
- What else is mixed in?
- What are current labor requirements for collection?
- What does the current storage infrastructure consist of?

IV. Byproduct Potential
- What are current liquid fertilizer practices and costs? Is there farmland associated with the dairy?
- What are current bedding practices and costs? Potential for composting operation?
- Is there a potential use for waste heat? (Space heating, a greenhouse, water heating…)
- A market for RECs or carbon offsets?

V. Financial Assessment
- What are the current annual operating revenues and profits of the farm?
- How much capital or financing is available on the farm?
- What is the farm's credit and external financing potential through loans, grants, etc?
- What is a realistic time horizon/payback period for the farm?

VI. Farmer Willingness and Expertise
- What is the farmer's technological expertise level? Willingness to learn?
- How much risk is the farmer willing to take on?
- What are the time and operational constraints of the farmer?
- Would the farmer be interested in a digester cooperative? If so, what are local farm demographics?
- Would the farmer be more interested in a digester were it built and operated on their property by a state agency or private firm?

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